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THESIS

APPLICATION OF THE WENGER TAXONOMY FOR CLASSIFYING GOODS PROCURED BY THE FEDERAL GOVERNMENT TO COMMERCIAL OFF-THE-SHELF COMPUTER HARDWARE EQUIPMENT

by

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APPLICATION OF THE WENGER TAXONOMY FOR CLASSIFYING GOODS PROCURED BY THE FEDERAL GOVERNMENT TO COMMERCIAL OFF-THE-SHELF COMPUTER HARDWARE EQUIPMENT

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ABSTRACT

The Wenger Taxonomic Model provides a means to classify goods procured by the Federal Government so as to provide procurement professionals with strategic buying insight. Several aspects of the model have been explored by various researchers. These researchers have found that the model is both valid and useful. This study focuses on application of the Wenger Taxonomic Model to Commercial Off-the-Shelf computer hardware equipment procured by a specific buying activity. It proposes a slightly different version of the Wenger Taxonomic Model. It also proposes five areas where the model would help procurement professionals make smarter Information Technology investments. These areas are: cost-benefit analysis, source selection evaluation, warranty purchases, contingency contracting, and evaluating the organizational impact of Information Technology acquisitions.

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I. INTRODUCTION

A. BACKGROUND

The Department of Defense (DoD) and all Federal Government agencies continue to implement a steady stream of acquisition reforms. These reforms are necessary, in part, because of declining budgets, evolving missions, and rapidly changing commercial marketplaces. The DoD cannot meet the demands of the future unless it alters its procurement practices to accommodate these factors. Ultimately, these practices must strive to obtain a needed product at the right time, at the right price, and with minimal administrative waste.

A procurement area ripe for reform is the acquisition of Information Technology (IT) because its efficient, effective procurement is problematic. In 1996, the United States Congress defined IT as:

> ...any equipment or interconnected system or subsystem of equipment, that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information...includes computers, ancillary equipment, software, firmware and similar procedures, services (including support services), and related resources (U.S. Congress, 1996, pp. 39, 40).

This definition suggests the enormity of the problem. First, as defined above, all Government agencies require this technology to accomplish their daily functions.

Second, because of other reform initiatives, almost all of the technology contains some Commercial Off-the-Shelf (COTS) components. Third, and again because of other reform initiatives, major system acquisitions that may seem inherently unique to the Government usually contain many COTS sub-systems. Ultimately, there are many organizations that have a need for IT, and as often as not, have differing opinions about the proper way to determine requirements, to procure the requirement and to support it.

The problems listed above, and many others, were addressed recently the passage of Public Law 104-106, the Information Technology Reform Act (ITMRA) of 1996 (otherwise known as Subdivision E of the Clinger-Cohen Act). The requirements of this law are summarized in a 2 June 1997 Secretary of Defense memo in which it states that the ITMRA,

> In particular focused on the need for Federal Agencies to improve the way they select and manage information technology resources...to help ensure that investments in information technology provide measurable improvements in mission performance (Cohen, 1997, p.1).

The same memo also contains broad philosophy that must be adopted by DoD to successfully implement the ITMRA requirements. They are:

- To embrace new ways of doing business.
- To understand and participate in the process of change.

- To appreciate the need to treat technology expenditures as investments. (Cohen, 1997, p.2)

The ITMRA has and will continue to have an impact on the way procurement professionals determine, buy, and support information technology acquisitions. If a broad goal of the ITMRA is to improve the way DoD acquires this technology, then the researcher believes the Wenger Taxonomic Model for the Goods Purchased by the Federal Government (hereafter referred to as the Wenger Model) provides a potentially simple tool for procurement personnel to improve their ability to meet this goal.

In 1990, Brian Wenger successfully developed a taxonomic model for classifying goods procured by the Federal Government. His model theoretically gives procurement professionals the ability to categorize a good as either simple, basic, moderate, advanced, or complex by using a small set of characteristics considered inherent to the good. In 1991, John Prendergast validated the model. After Prendergast, other researchers explored various applications of the model. This body of research examined the model's potentially useful applications and the associated benefits. In general, the body of research found that the Wenger Model is a viable tool for classifying goods procured by the Federal Government.

If acquiring computer hardware equipment is similar to acquiring other goods, then the model might be usable for computer hardware classification. The researcher, in this thesis, explores this idea by repeating some of the procedures developed by Wenger and then analyzing the results in relation to a particular buying activity (computer hardware equipment procured by the Marine Corps' Common Computer Resources Program Office).

Proper management of computer hardware procurements is essential for successfully accomplishing ITMRA objectives. The Wenger Model might provide a vehicle for improving the management of such procurements. If computer hardware procured by the Common Computer Resources (CCR) Program Office is classifiable then it would open many opportunities for research into improving its current procurement practices.

Classified subject matter is usable subject matter. In an era of acquisition reform and declining budgets, it is critically important that decision makers have information that is in a succinct, usable form. More important, the information needs to be of value. Informed, good decisions lead to smarter procurements and reduced risk in the contracting and acquisition environment. A sound method of classifying computer hardware equipment that the Federal Government procures could do much to improve decisionmaking.

B. OBJECTIVES

The primary objective of this study was to determine the viability and subsequent results of using the Wenger Model for classifying computer hardware equipment procured by the Marine Corps' CCR Program Office. Specific objectives included:

- Determining consequent categorical placement of computer hardware items that comprise various Marine Common Hardware Suites (MCHS).
- Identifying categorical differences between various items and what, if any, impact these differences have on existing procurement practices.
- Determining what Wenger Model characteristics have an impact on the categorical placement of items.
- Determining how the Marine Corps CCR Program Office and IT procurement professionals can improve their procurement practices through use of the Wenger Model.

C. RESEARCH QUESTIONS

The following primary research question addressed the objectives of this study:

- What would be the results of using the Wenger Taxonomical Model for classifying goods procured by the Federal Government when it is used to classify computer hardware equipment procured by the Marine Corps' Common Computer Resources (CCR) Program Office?

The following subsidiary research questions were applicable to the study:

- What types of computer hardware equipment typically receive high-end categorical placement and what are the contributing characteristics?

- What are the principal differences and similarities between computer hardware equipment and their importance to the procurement process?

- How does the behavior of characteristics affect the overall categorical placement of all computer hardware equipment?

- How can the CCR Program Office and other IT procurement professionals benefit from using the results obtained from the Wenger Model?

- What improvements or enhancements can be made to the Wenger Model to improve its ability to classify computer hardware?

D. RESEARCH METHODOLOGY AND ORGANIZATION OF STUDY

The research for this thesis was accomplished by completing the following:

- Literature review.

- Site visit to the buying activity.

- Determination of types of computer hardware used for classification.

- Development of survey.

- Data collection.

- Analysis of data.

- Application of data to the classification scheme.

The researcher first and continually conducted a review of literature relating to taxonomic classification, computer

hardware terminology, and information technology acquisition. The results of the review of taxonomic classification literature are contained in Chapter II.

Next, the researcher conducted a site visit to the Marine Corps System Command (MARCORSYSCOM) CCR Program Office. The purpose of this visit was twofold. First, it was to precisely determine what types of computer hardware equipment were bought by this organization. Second, it was to determine how the organization procured this equipment. The results of the information obtained from this site visit are contained in Chapter III.

The researcher developed a survey after determining the types of computer hardware equipment bought by CCR. The survey was developed for transmission and completion through the Internet. It was sent to a wide variety of organizations for completion. These topics are addressed in Chapter IV.

After receipt of the data, it was analyzed. Analysis included: 1) Determining the results of using the Wenger Model, 2) Determining if a different version of the Wenger Model produced more useable results, and 3) A comprehensive look at the way Wenger Model characteristics affect the categorical placement of items. The results of this analysis are contained in Chapter V.

Based on this analysis, the researcher derived various conclusions relating to ways in which the CCR Program Office and other IT procurement professionals can benefit from using the Wenger Model. Furthermore, analysis led the researcher to discuss the impact the results of using the Wenger Model have on the procurement of IT equipment. This discussion is contained in Chapter VI.

Chapter VII presents the conclusions and recommendations of the researcher regarding this research effort.

Based on this analysis, the researcher derived various conclusions relating to the primary and subsidiary research questions as well as recommendations for improving the Wenger Model as it applies to computer hardware classification. This discussion is contained in Chapter VI.

E. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The scope of the study is limited to determining the results of applying the Wenger Model to the classification of computer hardware procured by the Marine Corps' CCR Program Office. Intrinsic to this goal was the determination of the model's viability for computer hardware classification. Based on the classification results, the study draws conclusions relating to CCR Program Office procurement and buying practices as well as ways to improve the Wenger model itself.

The following assumptions apply:

- The surveyed personnel had adequate knowledge about the items contained in the survey in order to classify them.

- The surveyed personnel could complete the survey without needing education in the fundamental aspects of taxonomic classification.

- The original twelve characteristics analyzed by Wenger are sufficient for testing the model with relationship to computer hardware.

The following limitations apply:

- The computer hardware equipment analyzed by this study is not all encompassing. It is limited to COTS equipment procured by the CCR Program Office.

- Survey respondents had a difficult time conceptualizing computer hardware equipment as anything other than complete systems.

F. LITERATURE REVIEW

The fundamental resources for this study were the graduate theses of Wenger and Prendergast. Wenger's thesis, entitled "A Taxonomical Structure for Classifying Goods Purchased by the Federal Government,"(Wenger, 1990) concerned the development of a model which could be used to gain insight into strategic buying practices. Wenger's model was used in this study. Prendergast's thesis, entitled "Application of a Taxonomical Structure for Classifying Goods Procured by the Federal Government," (Prendergast, 1991) validated the Wenger Model. Both theses

provided substantial access to other literature that explained the theory and logic of taxonomical classification.

Other resources important to this study were various Government documents relating to the implementation of the ITMRA. These documents established agency policy for compliance with the provisions of the Act. Other Government documents included policy relating to the conduct of the CCR Program Office.

G. CONCLUSION

This chapter briefly introduced the Wenger Model and its potential application to the classification of computer hardware procured by the CCR Program Office. It also outlined the researcher's methodology, the format of the study, objectives of the study, and the researcher's primary and secondary research questions. The next chapter provides a detailed explanation of taxonomical classification and the development of the Wenger Model.

II. TAXONOMIC CLASSIFICATION AND THE WENGER MODEL

A. PURPOSE

This chapter introduces the concepts of contracting as a science and its relationship to taxonomic classification. It examines some uses of various taxonomic classification schemes and their potential application to procurement research. Furthermore, the chapter explores the development and subsequent validation of the Wenger Model. The focus of this chapter is to:

- Examine taxonomic classification.
- Explore the benefits of taxonomic classification in relation to procurement.
- Review the Wenger Model and associated subsequent research conducted in the taxonomy of goods procured by the Federal Government.

B. INTRODUCTION

Can one consider contracting as a science? Many researchers have tackled this question in the last decade and for good reason. Effective, efficient contracting has become increasingly difficult in an era of declining budgets, continuous acquisition reform, and increasing public and legislative oversight. Government procurement specialists not only must quickly purchase the best item at the best price, but must also accomplish this in an era when

the procurement process has difficulty keeping pace with rapid product technological change. The researcher believes this is particularly true with respect to IT. John Lynn, in a study relating to classification and market research, summarized this problem well when he said, "This concept of contracting as a science arose as a direct result of the growing complexity and increasing difficulties encountered in the procurement process." (Lynn, 1994, pp. 10,11)

Considering the complexity of the procurement process and the many dynamic factors influencing its execution, Government procurement might benefit from a systematic organization of its functions as would occur if contracting were a science. Among the first to set about determining whether contracting could be considered a science was Steven Park(Park, 1986). Park, in a master's thesis, "recommended the development of a systematic and organized method for dealing with the field of contracting." (Beeson, 1993, p. 10)

In the thesis, Park proposed that sciences must have the following characteristics:

- A distinctive subject matter.
- The description and classification of the subject matter.
- The presumption of underlying uniformities and regularities concerning the subject matter.

- The adoption of the method of science for studying the subject matter. (Park, 1986, p.41)

Among the characteristics listed above, the second of them has received considerable attention in recent years and is the characteristic with which this study is concerned. Although the jury is still out with respect to determining the validity of the notion that contracting is a science, the research conducted with respect to the second characteristic suggests it might be true. Pivotal among this research was Brian Wenger's development of a taxonomic model for classifying the goods purchased by the Federal Government (Wenger, 1990). Before examining this model, however, it is imperative that one understands the purpose and principles of classification and the potential benefit of classification to procurement professionals.

C. DEFINITION OF TERMS

For the purposes of this study, the following definitions give the reader brief explanations of words and terms germane to taxonomy and classification:

- Taxonomy - The theoretical study of systemic classifications including their bases, principles, procedures and rules. The science of how to classify and identify.

- Classificatory System - The end result of the process of classification, generally a set of categories or taxa.

- Classification - The ordering or arrangement of entities into groups or sets on the basis of their relationships, based on observable or inferred properties.

- Identification - The allocation or assignment of additional, unidentified objects to the correct class, once such classes have been established by prior identification.

- Taxon - A group or category in a classificatory system resulting from some explicit methodology. The plural is taxa.

- Units - Objects and entities that are identified as belonging to one or more taxa constituting a classificatory system. Identification is based on an explicit methodology focusing on the similarities/dissimilarities of the units. (Fleishman and Quaintance, 1984, p.22)

D. PURPOSE OF CLASSIFICATION

The purpose of classification and its subset taxonomic classification are as wide and varied as there are people and phenomena to classify. Ultimately, however, the goal of classification, regardless of the method used to obtain the classification, is to provide order to phenomena so as to better understand their complexities. Robert Sokal succinctly summarized this concept when he wrote:

> The paramount purpose of a classification is to describe the structure and constituent objects to each other and to similar objects, and to simplify these relationships so that general statements can be made about the classes of objects (Sokal, 1974, p. 1116).

Sokal also described various elements that a classification scheme must possess if it is to be useful. These elements are:

- Economy of memory.
- Ease of manipulation.
- Ease of information retrieval.
- Description of the structure and relationship of constituent objects. (Sokal, 1974, p. 1116)

If the classification scheme can meet the objectives noted above, then it can be used to gain a better understanding of the complexity of various phenomena. Wenger apparently developed such a scheme. This scheme was subsequently used by other researchers to explore such varied areas as market research, workload management, and procurement training. This study continues to apply Wenger's scheme with respect to computer hardware classification and its associated procurement.

E. PRINCIPLES OF CLASSIFICATION

Classification systems partition objects into categories that are homogenous with respect to selected characteristics. Classification systems also involve partitioning events or other phenomena, but this study is limited to systems involving objects. The two methods for

generating classification schemata are logical partitioning and grouping. (Hunt, 1983, p. 349)

Of these methods, logical partitioning requires that classification schemata be developed before data are analyzed; thus, a classification system is imposed on the data. Furthermore, it presupposes a fairly complete understanding of the phenomena under investigation. The procedure for using logical partitioning is to:

- Specify the phenomena for characterization.
- Determine the properties or characteristics on which the classification schema will be based.
- Label the categories that emerge from applying the properties or characteristics to the phenomena. (Hunt, 1983, pp. 349-353)

The results of logical partitioning usually are that all members of a category will possess all properties or characteristics used to identify the category. Logical partitioning might also result in empty categories or categories to which no phenomena belong. (Hunt, 1983, pp. 350-353)

Grouping or numerical taxonomy differs from logical partitioning in that the classification schema is generated after data are analyzed. Like logical partitioning, grouping starts by specifying the phenomena for characterization but does not determine the categories until

after, and as a result of analysis of associated data. (Hunt, 1983, pp. 349, 350)

Grouping usually results in classifications where the phenomena in any class may share many common characteristics but no individual phenomena need possess all of the characteristics of the class. Furthermore, unlike logical partitioning, grouping does not result in empty categories since categories are formed from observations derived from existing data. (Hunt, 1983, p. 354)

Wenger's scheme for classifying Federally procured goods used the grouping method. (Wenger, 1990) There are several reasons that support his choice for employing this method that have been noted by other researchers. These reasons are briefly summarized below:

- Because of the diversity of goods procured by the Federal Government, logical partitioning would result in either too many categories, or categories based on no more than two or three characteristics. (Sheehan, 1992, p.14)

- Grouping procedures handle large numbers of categorical properties better than logical partitioning. (Lynn, 1994, p.13)

- Grouping procedures require substantially less knowledge concerning which specific properties are likely to be powerful for classification phenomena than does logical partitioning. (Lynn, 1994, p.13)

F. EVALUATION CRITERIA

To date, Wenger's classification system for goods procured by the Federal Government has proven effective and

workable. This was clearly evidenced in research conducted by John Prendergast (Prendergast, 1991) in which he validated the system by applying it to three sets of homogenous goods. Prendergast found that Wenger's system met the criteria suggested by Shelby Hunt in his work, Marketing Theory, (Hunt, 1983) for evaluating alternative classification schemes. The criteria suggested by Hunt were:

- The classification scheme should adequately specify the phenomena to be classified.
- The scheme should adequately delineate the characteristics used in classifying.
- The scheme's categories should be mutually exclusive(e.g., the item should fit into only one category).
- The scheme's categories should be collectively exhaustive (e.g., every item is put into a category. A large number of items in a miscellaneous grouping indicate a flawed system).
- The classification scheme must be useful.
- The system should be internally homogenous (e.g., the items within the categories should be separate and distinct from items in other categories). (Wenger, 1990, p.15)

The researcher believes that some of these criteria are important when classifying computer hardware equipment. The criteria which this researcher feels are relevant to this study are discussed in the following paragraphs.

The first criterion suggests that the Wenger Model must indicate exactly what is being categorized(Wenger, 1990,

p.15). Can computer hardware equipment be lumped into a scheme that classifies all goods procured by the Federal Government or is computer hardware so unique that it is not adequately indicated by the model?

The second criterion, as noted by Wenger, implies that characteristics should differentiate the items to be classified, be relevant to the scheme's end-use goal, and be ascertainable to classification participants and users (Wenger, 1990, p.15). Do the characteristics differentiate separate computer hardware components? Are they of value after classification is complete? Can participants understand characteristics as they relate to the item?

The fifth criterion, that the scheme must be useful, is particularly important to this study. Computer hardware items might be classifiable by using the Wenger Model but is this classification useful? Are the classified items presented in such a manner that procurement professionals could draw sound conclusions about strategic buying implications?

G. POTENTIAL BENEFITS OF CLASSIFICATION

As previously noted in Chapter I, efficient, effective procurement of computer hardware equipment is problematic. Briefly, this is because:

- All Government agencies require this technology to accomplish their daily functions.

- Almost all of the technology contains some Commercial Off-the-Shelf (COTS) components.

- Major system acquisitions that may seem inherently unique to the Government usually contain many COTS sub-systems.

- There are many organizations that have a need for IT, and as often as not, have differing opinions about the proper way to determine requirements, to procure the requirement and to support it.

A viable classification scheme of goods procured by the Federal Government, of which computer hardware is assumed to be a subset, might give all stakeholders associated with these products a better understanding of the computer hardware's particular nuances and thus enable them to make smarter decisions when purchasing the product. Broadly, the following benefits might be realized by using such a classification scheme (Prendergast, 1992, p. 22):

- Better understanding of the relationships between goods.

- Segregation of goods within commodity type.

- Differences in complexity or procurement procedures would be recognized in formulating regulations and policy.

- Accurate determination of acquisition strategies.

- Application in the logical budgeting of operating funds to contracting activities based on inherent characteristics of the item, vice other less descriptive measures such as unit price.

H. EXISTING CLASSIFICATION SCHEMES

The two commonly used classification schemes which apply to Federally procured goods are the Federal Supply Classification (FSC) and the Standard Industrial Classification (SIC). Other schemes include classification based on dollar value of transactions and classification based on origin, i.e., COTS or developmental. (Beeson, 1993, p. 15) Presumably, each of these schemes serves its intended purpose. They do little, however, to aid procurement professionals in decisionmaking. A brief discussion of the FSC and SIC systems follows.

1. Federal Supply Classification

This classification system separates categories of goods based on groups and classes within a commodity. Classes are determined based primarily on the physical and performance characteristics of the goods. Goods often requisitioned together are included in the same class. (Beeson, 1993, p. 15) Based on the researcher's experience, this system is principally used as a supply management tool. This is because goods are categorized after they have been procured. Once a good is in a supply system, the classification system provides personnel the ability to systematically order the good. The system does nothing to provide insight into the most effective method to procure the good.

2. Standard Industrial Classification

This classification system is economic activity based and reflects the structure of the U. S. economy. The system describes and organizes business establishments based on their primary activity or predominant product. It provides a method to collect data for tabulation and presentation on businesses. The system does not classify goods based on their inherent characteristics. (Beeson, 1993, p.16) Because the system does not classify goods based on their inherent characteristics, it does not provide a means to draw strategic insights into particular goods.

I. THE GORDON MIRACLE CLASSIFICATION SCHEME

Dr. David Lamm and Wenger, in an article entitled "A Proposed Taxonomy for Federal Government Goods," acknowledged that both of the systems described above serve a useful purpose but do not satisfy the need for strategic classification of goods because neither provides insight into the Government procurement process. (Lamm and Wenger, 1990, p.240) Because of these shortfalls, Wenger looked to other classification schemes to aid in development of a model which would provide procurement professionals with strategic insights into the goods they were procuring. That scheme was one developed by Gordon Miracle. This scheme

formed the foundation of Wenger's model and serves as a good introduction to the Wenger model itself.

In 1965, Miracle published a classification system for goods based on product characteristics. This system was motivated by an attempt to link product characteristics with marketing strategies(Wenger, 1990, p.20). Miracle's system sought to logically group products based on the characteristics found in Table 2-1.

Based on these characteristics, Miracle developed a matrix that subdivided products into five categories and linked those categories to his assigned product characteristics. Values of 1 through 5 were associated with descriptive values. Table 2-2 provides a snapshot of this matrix.

Miracle Characteristics

1. Unit value.
2. Significance of each individual purchase to the consumer.
3. Time and effort spent purchasing by consumers.
4. Rate of technological change (including fashion changes).
5. Technical complexity.
6. Consumer need for service (before, during or after sale).
7. Frequency of purchase.
8. Rapidity of consumption.
9. Extent of usage (number and variety of consumers and variety of ways in which the product provides utility).

Table 2-1(Miracle, 1965, p.20)

Miracle Groupings

Product Characteristic	Group I	Group II	Group III	Group IV	Group V
1.	Very low	Low	Med to High	High	Very High
2.	Very low	Low	Medium	High	Very High
3.	Very low	Low	Medium	High	Very High
4.	Very low	Low	Medium	High	Very High
5.	Very low	Low	Med to High	High	Very High
6.	Very low	Low	Medium	High	Very High
7.	Very High	Med to High	Low	Low	Very low
8.	Very High	Med to High	Low	Low	Very low
9.	Very High	High	Med to High	Low to Med	Very low

Table 2-2 (Wenger, 1990, p.22)

Ultimately, various products would receive subjectively assigned values corresponding to each of the nine characteristics. These values would then be averaged, and a product could then be assigned to one of the five groups. Miracle found that products such as candy bars, soft drinks, and razor blades fell into group I while products like steam turbines, electrical generators, and machine tools fell into group V. Various other products fell in a spectrum between these two groups.

The benefit of being able to categorize products in this fashion is that, as Miracle suggested, it "allowed the businessman to develop strategic plans for policy and marketing mix." (Prendergast, 1991, p.26) This ability to gain strategic insight into products was a compelling reason to attempt a similar classification with respect to goods procured by the Federal Government. If a model could be

developed that would give procurement professionals a tool to quickly classify goods, then perhaps this tool would also serve to improve the ability to effectively and efficiently procure goods that provided customers the best product at the best price. Wenger sought to develop such a model, and it is here that we turn to his development of that model.

J. THE WENGER TAXONOMIC MODEL

As previously noted, Wenger's model relies heavily on the work of Gordon Miracle. The basis for the model was to classify goods procured by the Federal Government so as to offer strategic insight into the buying process (Lynn, 1994, p.23). The following paragraphs discuss Wenger's development and testing of the model.

First he created a list of twenty-two characteristics. Wenger formulated the characteristics based on literature review and his personal experience. (Wenger, 1990, p. 27)

He then sought to gain affirmation of the characteristics by interviewing twelve expert panel members who were National Contract Management Association (NCMA) Fellows. These personnel were chosen because of their contracting expertise and previous research associated with the possibility that contracting is a science. As a result of these interviews, Wenger derived twelve additional characteristics worthy of consideration. (Wenger, 1990, pp. 28-30)

Based on his own belief, Wenger then grouped the characteristics into three dimensions (characteristics associated with the goods, the buying process, and the environment). Wenger felt that a three-dimensional analysis of these characteristics would be too difficult to accomplish. He decided to limit the analysis principally to those characteristics associated with the good. He did, however, include in a single grouping three characteristics associated with the environment and one associated with the buying process. The revised list of twelve characteristics is shown in Table 2-3. Again, based on his own experience plus expert panel input, Wenger defined each characteristic. These definitions are at Appendix A. (Wenger, 1990, pp. 30-33)

Wenger Characteristics

1.	Change	7.	Unit cost
2.	Complexity	8.	Documentation
3.	Customization	9.	Item attention
4.	Maintainability	10.	Sources of supply
5.	Homogeneity	11.	Criticality
6.	Consumption	12.	Stability

Table 2-3 (Wenger, 1990, p.25)

At this point, Wenger drew on the research of Gordon Miracle. Like Miracle, he developed a matrix and scaled each characteristic in a range of one to five. For example,

the characteristic "complexity" was scaled from (1) very low technical complexity to (5) very high technical complexity. The scales associated with the characteristics are contained with the definitions at Appendix A. Wenger felt that the advantage of using a matrix was that it held an "intuitive appeal of an uncomplicated visual presentation." (Wenger, 1990, p.37)

After developing the matrix and selecting the scales, Wenger then selected twenty-one goods to analyze. To select the goods, Wenger sought ones that were recognizable and self-explanatory, and ones that he believed ranged from simple to complex (sandpaper versus nuclear reactor). (Wenger, 1990, p.43) The goods that Wenger selected are at Appendix B.

Wenger then surveyed 139 NCMA fellows essentially asking them to assign characteristic numerical values (scales) to the twenty-one different goods. He performed cluster analysis on the data and determined that six of twelve characteristics did not need to be evaluated to determine the ranking or categorical placement of a particular good. Consequently he was left with six characteristics that could be used to draw strategic buying conclusions. Those characteristics were: complexity, customization, maintainability, unit cost, documentation,

and item attention. An example of Wenger's classification scheme can be found at Appendix C.

K. PRENDERGAST VALIDATION

Despite the apparent success of the Wenger Model, Wenger made a recommendation that future classification efforts should focus on families of goods. He felt it might be useful to examine goods within a commodity type that exhibit a wide range of characteristics or examine goods bought by a single organization that buys a wide variety of them. Additionally, Wenger thought it might be useful to examine a set of homogenous goods rather than the set of heterogeneous goods that he tackled. (Wenger, 1990, pp.95,96)

Prendergast, in his study, addressed these possibilities. He applied the model to DoD buying organizations (Naval Aviation Supply Center and Defense General Supply Center). Furthermore, unlike Wenger, the model derived its input strictly from buyers and in accordance with Wenger's recommendation, the organizations procured a wide variety of goods that could be homogeneously grouped.

Using much the same methodology as Wenger, Prendergast found that through cluster analysis he could eliminate the same six characteristics as did Wenger. He concluded that

the scheme as it was designed was valid and could be a useful procurement tool. (Prendergast, 1991, p.81)

L. SUMMARY

This chapter examined the principles of classification and taxonomic classification. It also reviewed the development and validation of the Wenger Model. This model forms the basis for this study as it applies to the acquisition of COTS computer hardware equipment. The next chapter will discuss the environment in which computer hardware equipment is currently being procured. It will also discuss the organizational structure and procedures employed by the MARCORSYSCOM CCR Program Office to procure the computer hardware equipment around which this study revolves.

III. INFORMATION TECHNOLOGY ACQUISITION

A. PURPOSE

This chapter discusses the current acquisition environment and its impact on the procurement of IT. Specifically, it discusses the Information Technology Management Reform Act of 1996 and the consequences, to date, of its implementation. Using this as a backdrop, the chapter ends with discussion of how the Marine Corps is partially implementing the requirements of the Act through actions taken by its CCR Program Office.

B. INTRODUCTION

Many facets of the DoD's acquisition practices are changing because of external factors beyond its control. Broadly, these changes can be traced to a significantly diminished military threat and the resulting "peace dividend," i.e., reduced defense expenditures (down 60% from its peak in 1985). Although IT acquisition practices have been influenced by these events, a more salient reason was noted by the General Accounting Office (GAO) when it stated that, "Congress and the public have increased their demand for a smaller government that provides services at a lower cost." (U.S. GAO, 1996, p.2) Acquisition of relevant IT is crucial to this success. As GAO would have it, this is

because smart investment in IT can dramatically affect one's ability to improve the management of personnel, knowledge and information, and capital property/fixed assets. (U.S. GAO, 1996, p. 16)

In fiscal year 1994, the Federal Government spent upwards of $23.5 billion on IT products and services. This represented about five percent of all Government discretionary spending. Despite this hefty outlay and presumably greater outlays in FY '95 and '96, GAO points out that:

> The impact of this spending on improving agency operations and service delivery has been mixed at best. Federal information systems often cost millions more than expected, take longer to complete than anticipated, and fail to produce significant improvements in the speed, quality, or cost of federal programs (U.S. GAO, 1996, p. 2).

This comment suggests that the Federal Government can improve its operations through better management of its IT acquisitions. The GAO feels that it is not the cost of a system that is the determining factor, but how the acquisition is selected, designed, and implemented. In short, the GAO says, "In this age of constrained resources, federal executives must find ways to spend more wisely, not faster." (U.S. GAO, 1996, p. 2) The ITMRA represents a step in that direction.

C. INFORMATION TECHNOLOGY MANAGEMENT REFORM ACT

In 1996, Congress passed the ITMRA, otherwise known as the Clinger-Cohen Act. This Act decentralized IT procurement out of the hands of the General Services Administration (GSA). Essentially, it gave executive branch agencies the authority to procure IT without going through a clearinghouse organization like the GSA. With this newfound capability, however, agencies gained new responsibilities. Gloria Sochon, writing in Contract Management said that:

> Each executive agency must establish a capital planning and investment control process for maximizing the value and assessing and managing the risks of its IT acquisitions. This process treats IT acquisitions as investments, integrating IT investment decisions with budget, financial, and program management decisions. Agencies need to develop quantitative criteria to use for comparing and prioritizing alternative information systems projects. They need to identify quantitative measures for determining the net benefits and risks of an investment. They also need to provide for identifying IT investments that could result in shared benefits or costs for other federal agencies or state or local governments (Sochon, 1997, p. 6).

Of consequence to this study, the ITMRA did the following: (Lukschander, 1997, pp. 4,5)

- Eliminated GSA as the Federal Government's procurement authority on IT acquisitions.
- Eliminated the requirement for agencies to obtain a Delegation of Procurement Authority.
- Changed IT procurement to an investment oriented focus that emphasizes IT as a tool for improving mission performance.

- Instructed executive agencies to establish performance measures for IT investments.

D. EFFECTS OF THE CLINGER-COHEN ACT

A noticeable effect of the Clinger-Cohen Act has been a surge of available multi-agency procurement vehicles (Luarent, 1997, p.36). GSA schedules are no longer mandatory. Many agencies have negotiated Indefinite-Delivery, Indefinite-Quantity (IDIQ) contracts, established Blanket Purchase Agreements (BPAs), or developed other innovative contract vehicles on multiple award schedules to obtain IT requirements (Luarent, 1997, p. 36). Any Federal agency can tap into these pre-existing arrangements. Furthermore, these agencies can negotiate lower prices and there is no maximum order limitation. In some respects, this has proven to be a windfall for some agencies. The relaxation of rules brought on by Clinger-Cohen has made technology more accessible and easier to obtain. Users are buying more frequently and in greater volume. In 1996, for example, the Federal Supply Service (FSS) picked up $1 billion in IT business. (Luarent, 1997, p. 36)

An example of this transfer of business can be found at the Naval Information Systems Management Command (NISMC). In 1996, NISMC awarded four three-year BPAs worth $90 million for upwards of 23,000 desktop personal computers and servers. (Luarent, 1997, p. 36) NISMC replaced its own IDIQ

contracts with BPAs. They did this because they decided FSS BPAs were the best vehicles for their large IT contracts. One benefit of this decision was the elimination of huge Request for Proposals (RFPs) and even larger vendor proposals. (Laurent, 1997, p.36)

There are, however, potential negative consequences when the DoD and other agencies procure IT in this manner. As recently as April 1997, OMB officials acknowledged that "agencies could drown the federal market with too many homegrown indefinite-delivery, indefinite-quantity (IDIQ) contracts." (Power, 1997, p. 53) The potential impact of this is to reduce agency negotiating leverage. This is because too many available options reduces purchasing volume on an individual contract. Reduced volume may affect the ability to negotiate lower prices. (Power, 1997, p. 53)

Another potentially negative aspect of this flood of available contract vehicles are rising administrative costs (Power, 1997, p. 53). Admittedly, they are lower than traditional contracting methods, but cumulatively they may add up to greater administrative costs. As a result of the above consequences and other factors, Peter Weiss, a senior policy analyst with the OMB's Information Policy and Technology Branch stated that, "The administration is watching for problems resulting from too many agencies

running too many similar procurements, especially in the high-end workstation arena." (Power, 1997, p. 53)

A final item worth mentioning is the environment in which industry is working while Government agencies implement Clinger-Cohen. In the opinion of one observer, the IT industry is currently operating under the premise that "customers don't want to deal with several vendors." (Caron, 1997, p. 93) In other words, vendors are providing customers such complete IT packages that customers have no incentive to seek a variety of IT sources. These packages may include hardware, software, support services, warranty options, and upgrades.

The researcher believes this industry philosophy can affect users in critical ways. For example, a significant effect could be that customers (including the Government) are sacrificing product capability for consistency of service. Customers, although provided with a multitude of options, might have difficulty combining their particular hardware requirements into one system. For example, a customer might want to purchase a certain level of memory but can only purchase the memory if they also purchase a 16X CD-ROM (even if they do not need or desire the latter technology). Inevitably, the purchase of a system results in the establishment of a customer/supplier association. This association may be strengthened by product service

agreements. Ultimately, when a system needs replacement or upgrade, the customer is not as likely to switch vendors because it is easier to keep the status quo. In the end, customers have difficulty buying the best, integrated, top-of-the-line equipment because vendors do not package it that way. Conversely, customers may also be compelled to purchase capability that they do not need because of this packaging philosophy.

Clinger-Cohen has made the procurement of IT equipment easier. It has forced agencies to cooperate and undoubtedly has saved money. Furthermore, it has forced agencies to treat IT as an investment, an investment that must show some tangible benefit. Clinger-Cohen has also made available many IT procurement options. This availability is complicated by an industry philosophy that tells the customer what he or she wants rather than the other way around. The researcher believes that one must fully understand the perceived IT requirement before entering into this marketplace. The customer must be able to identify what factors concerning IT equipment are important as they relate to strategic buying. The Wenger Model potentially provides an avenue for improving this understanding particularly if it can be integrated into the process the Marine Corps uses to purchase its commercial IT hardware requirements.

E. MARINE CORPS IMPLEMENTATION OF CLINGER-COHEN

The following paragraphs steps the Marine Corps has taken to implement provisions of Clinger-Cohen.

In November 1996 it issued interim IT acquisition policy which stressed that IT acquisitions must comply with ASN(RDA) interim policy issued August 1996. This policy eliminated Delegation of Procurement Authority (DPA) requirements, allowed agencies to issue multi-agency use IDIQ solicitations and award contracts based on those solicitations. Acquisitions of less than $120 million did not need formal Assistant Secretary of Defense (ASD) review. (Lukschander, 1997, pp. 20, 21)

It Began compliance with SECNAVINST 5000.2B which allowed MARCORSYSCOM to be the designation authority and Milestone Decision Authority (MDA) for IT Acquisition Category (ACAT) III, IV, and Abbreviated Acquisition Programs (AAPs). This represented a significant increase from previously approved decision authority. (Lukschander, 1997, p. 22)

In March 1997, it issued a message which addressed IT acquisition policy. This message formalized MARCORSYSCOM as the Milestone Decision Authority (MDA) for IT AAPs and provided the definition of an IT AAP. An IT AAP was defined as one in which the program costs were less than $15 million for one year, had total program costs less than $30 million,

and was a program not requiring operational testing. (Lukschander, 1997, p. 25)

MARCORSYSCOM further delegated ACAT designation authority and MDA to the Commanding General, Commanding Officer, and HQMC Flag and Senior Executive levels. (Lukschander, 1997, p. 25) This delegation, however, was more restrictive than that described above. The parameters of this delegation were:

- Total program cost less than or equal to $10 million.
- No software development.
- Capability intended to meet local requirements but not fielded Marine Corps-wide.
- Acquired assets in full compliance with USMC minimum desktop configuration and COTS software standards. (U.S. Marine Corps, March 1997, pp. 3,4)

Finally, this message also noted that policy and operating procedures were being developed which would establish common information technology acquisition vehicles managed by MARCORSYSCOM as the sole means for acquiring IT equipment assets (U.S. Marine Corps, March 1997, pp. 3,4). These policies are now developed and are partially manifested by actions taken in MARCORSYSCOM's CCR Program Office in relation to what this office calls Marine Common Hardware Suites (MCHS). Here, we turn to discussion of this office and its role in procuring IT for Marine Corps users.

F. COMMON COMPUTER RESOURCES (CCR) PROGRAM OFFICE

The primary mission of the CCR Program Office is to develop and maintain MCHS computers and peripherals for use by program managers, functional managers, the supporting establishment, and the Fleet Marine Force (Cruz, 1997, p. 2). As of October 1996, all MARCORSYSCOM Program Managers and Directors were required to use the CCR Program Office for the acquisition of their IT requirements (U.S. Marine Corps, October 1996, p. 1). Use of the CCR Program Office by external Marine Corps organizations was and still is optional, however, it is anticipated that all Marine Corps organizations will eventually have to use the CCR Program Office resources to obtain IT requirements. Associated with and in support of CCR's primary mission, CCR Program Office personnel:

- Ensure all MCHS products have viable contract vehicles and integrated logistics support plans.
- Provide technical support for project officers.
- Establish and manage IT support contracts for use by functional managers. (Cruz, 1997, p.2)

To accomplish the above goals, the CCR Program Office is broadly divided into three functional areas. These areas are requirements determination, acquisition, and contract administration. Requirements determination and acquisition are discussed in the following paragraphs.

1. Requirements Determination

The Marine Corps has developed and published minimum desktop personal computer and server configuration standards. These standards are designed to support connectivity and operations within the Marine Corps for major DoD-wide information systems (U.S. Marine Corps, 1997, p.1). The current minimum configurations are shown in Tables 3-1, and 3-2. Using these configurations as a foundation, the CCR Program Office divides MCHS requirements into an architecture containing UNIX-compatible Reduced

Desktop Configuration

Processor	Intel Pentium 166 MHz
BIOS	Flash BIOS
L2 Cache	256K
RAM	24MB Expandable to 128MB
Expansion Slots	2 PCMIA Type II
CD-ROM	8X CD-ROM Drive
Hard Disk	1.6 GB
Video	SVGA Graphics Accelerator with 3MB RAM
Monitor & Floppy Disk	17 Inch & 3.5 Inch, 1.44MB

Table 3-1 (U.S. Marine Corps, 1997, p.2)

Server Configuration

Processor	200 MHz Intel Pentium Processor
L2 Cache	512K with Pentium or 256K with Pentium Pro
RAM	64MB expandable to 128MB
Expansion Slots	4 EISA 32 bit expansion board
CD-ROM	8X CD-ROM Drive
Hard Disk	2 2GB or larger
Controller	1 EISA Fast Wide SCSI Controller
Tape Unit	1 4/8 Gigabyte 4MM Digital Audio
Floppy Disk	1 3.5 inch floppy drive (1.44MB)

Table 3-2 (U.S. Marine Corps, 1997, p.2)

Instruction Set Computers (RISC), IBM-compatible Complex Instruction Set Computers (CISC), and peripherals. These divisions are further subdivided into high performance and standard application categories which are again subdivided into rugged and non-rugged categories. The term rugged refers to the degree to which COTS equipment has been modified for use in environmentally hostile locations. Portable hardware equipment is embedded in the architecture and is also handled by the CCR Program Office. The architecture describe above is depicted in Figure 3-3.

MCHS Architecture

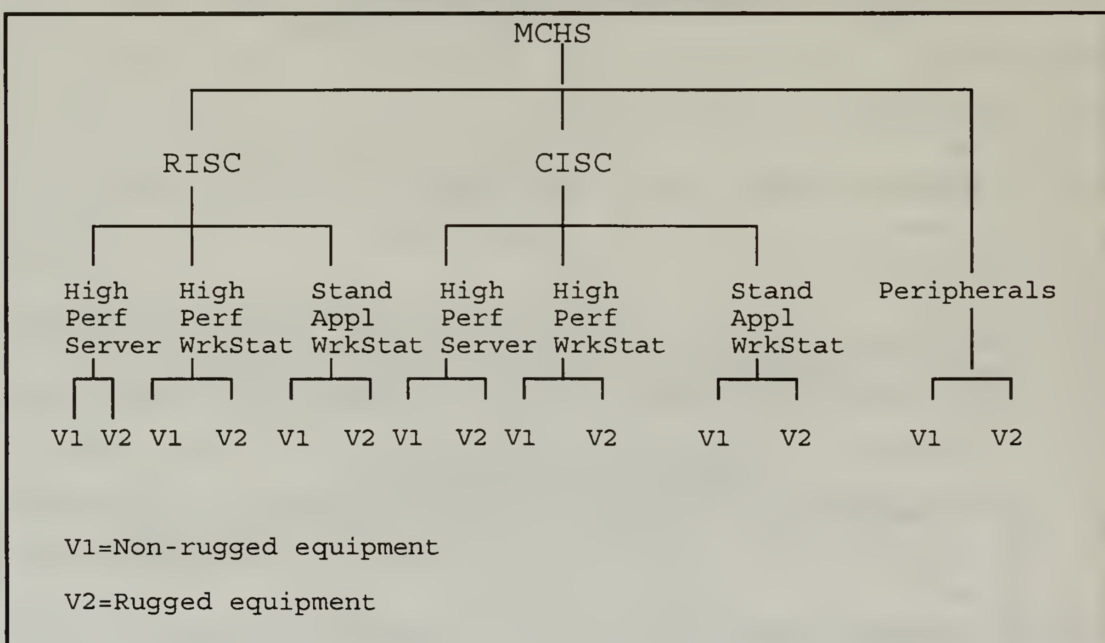

Figure 3-3 (Cruz, 1997, p.12)

Within this framework, the CCR Program Office considers the second level (RISC and CISC) as the Central Processing Unit's (CPU) architecture and the third level (high performance and standard application) as a system's level of

Unit's (CPU) architecture and the third level (high performance and standard application) as a system's level of performance and expandability. Within the third level, CCR categorizes systems as either high end, medium range, or low end. This categorization is not depicted in Figure 3-3. It is important, however, to describe this subdivision because the CISC IT equipment found within it is the family of goods the researcher analyzed using the Wenger Model. Abbreviated definitions of the equipment pertinent to this study are found in Appendix D.

Ultimately, those personnel in the CCR Program Office involved with requirements determination must do three broad things before any IT equipment is procured. They first validate the needs of the organization requesting the equipment (server, workstation, type of software activity). They then determine where within the established architecture a potential system will fall. Finally, they ensure that the system will meet minimum Marine Corps desktop and server configuration standards depicted in Tables 3-1 and 3-2. This is accomplished by verifying the CCR's Contracting Officer Technical Representative's (COTR) recommended MCHS acquisition solution for a specific requirement.

2. Acquisition

Responsibility for researching and recommending contracting options and identifying contract vehicles for approved MCHS configurations falls to the CCR's COTR section. Specifically, this section recommends MCHS equipment acquisition solutions for identified requirements. The COTR section accomplishes this by researching and developing contracting options for procuring MCHS items. Basically, this section searches available Federal Government IT contract vehicles (IDIQs, BPAs, etc.)to determine if MCHS items can be procured through one of these vehicles. For example, as recently as May 1997, Marine Corps organizations could procure a variety of equipment through various BPAs, National Institute of Health contracts, Navy basic ordering agreements, and GSA schedules. (U.S. Marine Corps, 1997, pp. 1-4)

The procedure noted above is incorporated into the decision process prior to placement or recommendation for placement of an item on the MCHS equipment list. Furthermore, contracting options are pursued to give the Marine Corps the greatest degree of competitive pricing, ordering and delivery flexibility, and quantity discounts.

A significant end result of this effort is CCR's quarterly publication of an MCHS Buyer's Guide. This document lists approved bundled IT configurations of COTS

equipment (with associated vendors) that can be purchased by MARCORSYSCOM PMs and other Marine Corps organizations for procurements that do not deviate from MARCORSYSCOM's established parameters. The bundled configurations are found in Appendix D.

G. SUMMARY

The Clinger-Cohen Act has changed the way Federal Agencies acquire IT requirements. Because of the relaxation of delegation of procurement authority and the elimination of mandatory GSA participation, the IT procurement arena has been flooded with a multitude of viable contracting vehicles by which to obtain IT equipment. Because of this, there now exists greater competition which theoretically should reduce prices and improve quality. A tradeoff, however, is that agencies may become beholden to the way in which the IT equipment industry markets their products. That is, they bundle their products and attempt to establish long-term vendor-user relationships. As Clinger-Cohen dictates, however, Agencies must operate within this environment and ensure that their IT procurements result in sound investments.

The Marine Corps is attempting to make sound IT investment decisions through their establishment of the MCHS concept. On the surface their efforts seem wise. They have established minimum equipment standards and seek to match

the requirements of users to these standards. Consequently, they have developed a variety of IT equipment configurations intended to meet the various levels of capability required by Marine Corps organizations. Using these configurations as a baseline, they have then sought to identify the most advantageous contracting vehicles available for a particular configuration. Ultimately, however, one must question whether or not this policy results in sound IT investments.

Use of the Wenger Model might provide some significant strategic insight into this question. The next chapter will discuss research methodology as it is linked to CCR's IT equipment configurations and the data obtained from this methodology.

IV. RESEARCH METHODOLOGY

A. PURPOSE

The purpose of this chapter is to summarize the research methodology used to apply the Wenger Model (outlined in Chapter II) to computer hardware equipment procured by the MARCORSYSCOM CCR Program Office (outlined in Chapter III). Research methods, the techniques used to provide cursory validation of the data, as well as significant data collection difficulties are discussed.

B. RESEARCH METHODS

The underlying motivations behind this research were to first determine what the results of using the Wenger Model with computer hardware equipment purchased by the CCR Program Office would be, and second to use these data to glean whatever strategic insight might be afforded through their analysis. The collection of data to be used in the classification effort was to be accomplished by soliciting input via survey from buyers, users, those involved with requirements determination, those involved with logistical support, and senior level managers. Furthermore, these personnel would not be members of a single buying organization but would represent a wide cross section of the DoD and other Federal Agencies involved in acquiring

computer hardware equipment. These data would then be analyzed using methods selected by the researcher but substantially affected by protocols used in Wenger's analysis and the research conducted by others relating to the Wenger Model. Ultimately, the resulting information could then be used to potentially provide strategic insight into how the CCR Program Office selects and procures its computer hardware equipment so as to improve its ability to make sound IT investment decisions as required by the Clinger-Cohen Act.

1. Selecting Items for Classification

In choosing the items for classification, the researcher relied on heuristics previously developed and used in a study conducted to validate the Wenger Model. Those heuristics used were:

> The items would need to be fairly recognizable. Since the sole identifier for the respondent was nomenclature, the aim was to select items that would have name recognition for even the most casual observer (Prendergast, 1991, p. 37).
>
> The items chosen would be of an equipment nature vice a piece part nature. Again due to the use of nomenclature to identify the item, it was felt that an item on the equipment level, would be less likely to generate confusion (Prendergast, 1991, p. 37).
>
> The items to be surveyed would be a part of a homogenous grouping (Prendergast, 1991, p. 37).

When considering these heuristics, it became apparent to the researcher that the items the CCR Program Office

associated with various CISC platforms displayed in Appendix D might be viable candidates for classification. The reasons for this assertion are outlined below.

First, the items listed in Appendix D are those items the CCR Program Office advertises in their "MCHS Computer Buyer's Guide." This document is available to all Marine Corps organizations that desire or are required to use the CCR Program Office for procurement of MCHS IT requirements. Presumably, those items that are listed are recognizable to those involved in the use or procurement of the platforms. The researcher believed that the breakdown of items provided in the guide lends itself to the requirement of the first heuristic that the item be fairly recognizable.

Second, the researcher believed that the items were of an equipment nature vice piece part as required by the second heuristic.

Third, the researcher believed that the items listed in Appendix D were sufficiently homogenous to classify. All listed items were related to computer hardware equipment, thus the requirement of the third heuristic was met.

Given the above, the researcher decided to classify those items listed in the CCR "MCHS Computer Buyer's Guide."

2. Selecting Survey Participants

Previous studies related to the Wenger Model were limited to input derived from buyers. The researcher

decided that this particular classification effort might be amenable to including input from a variety of personnel involved in computer hardware procurement. Several factors led to this decision.

First is the determination in previous studies that buyers might not be as knowledgeable about a product as one would assume. They might, for example, thoroughly understand an item's unit price but might not understand the same item's level of complexity or as in the words of one buyer, "I don't care about any of that stuff (the characteristics), I just buy it." (Researcher, 1997)

Second is the widespread involvement of all Federal Agencies in the procurement of computer hardware. Passage of the Clinger-Cohen Act opened the floodgates to a procurement area previously restricted to the GSA. The researcher saw this as an opportunity to solicit a wide variety of opinions from numerous sources.

Third is that the current acquisition climate encourages teaming. All personnel whether requirements, buyers or users should be participating in the acquisition of computer hardware equipment as a team, thus they should have more comprehensive understanding of all factors leading to the acquisition of a particular item.

Finally, the researcher considered the items selected for classification to be generic enough so that anyone

involved in the buying process, regardless of organization or function, should be able to intelligently discriminate between the items and characteristics.

Having decided on the population characteristics, the researcher contacted a wide variety of personnel in many organizations. Responses were received from all DoD Services, NASA, GSA, the Army Corps of Engineers, and other Federal Agencies. All tolled, 72 surveys were returned that were sufficiently complete for data analysis.

C. SURVEY DEVELOPMENT

In development of the survey, the researcher desired to make it as easy to complete as possible. The researcher believed that previous survey efforts relating to the Wenger Model were unwieldy and might inhibit personnel from responding. With the availability of the Internet and powerful software programs, the researcher felt that a survey instrument could be developed that might alleviate this problem.

Consequently the researcher decided to use Microsoft EXCEL as the conveyor of the survey. This software program allowed the researcher to put items selected for classification on one page. Furthermore, it allowed the researcher to embed definitions and associated scaling of characteristics in identifiable cells. The same definitions and scaling, however, were also included as a separate

document for those who were uncomfortable using the embedded notes.

Despite this perceived advantage, the researcher still felt the survey would be too unwieldy. After eliminating the redundant items contained in Appendix D, there remained 51 items requiring classification across 12 characteristics. This meant that survey respondents had to make 612 decisions. Consequently, the researcher decided to break the items into four separate surveys. Not only would this, the researcher believed, make it easier to complete, but it would also allow for a comparison across surveys. The final surveys are illustrated, absent instructions, in Figures 4-1 through 4-4. Surveyed items are listed in the far left column. Respondents were expected to enter numerical values under corresponding characteristics in accordance with the definitions and scaling contained in Appendix A.

D. CURSORY VALIDATION OF RESPONSES

The researcher felt there were at least two intuitive methods to validate whether or not the responses were reasonable without statistically analyzing them. The first method was to compare the average combined categorical placement of items in a particular MCHS system with that of others. For example, one would expect that the categorical placement of the combined like items of an IBM compatible

Survey 1

Item	Change	Complexity	Customization	Maintainability	Homogeneity	Consumption	Unit Cost	Documentation	Item Attention	Sources of supply	Criticality	Stability
200MHz processor w/integrated 512 KB level-2 cache												
512 MB of EDO RAM w/error checking and correction												
9.0 GB hot swap ultra wide SCSI drive												
4/8 GB internal DAT drive												
Dual channel PCI, integrated ultra wide SCSI & disk array controller												
Redundant power supply (internal power supply duplication)												
8X CD-ROM drive												
3.5", 1.44MB floppy drive												
SVGA controller w/1024X768 resolution w/16 colors and 1 MB RAM												
SVGA 15" monitor												
Type III PCMCIA slot												
4X CD-ROM drive												
28.8Kbs data/FAX modem												
10BT network interface controller												
Port replicator												

Figure 4-1 (Researcher, 1997)

Survey 2

Item	Change	Complexity	Customization	Maintainability	Homogeneity	Consumption	Unit Cost	Documentation	Item Attention	Sources of supply	Criticality	Stability
Enhanced keyboard												
Mouse												
10/100BT PCI network interface controller												
200MHz processor w/integrated 256 KB level-2 cache												
256 MB of EDO RAM w/error checking and correction												
4.0 GB hot swap ultra wide SCSI drive												
Dual channel PCI, ultra wide SCSI controller												
AT keyboard												
Trackball												
128 MB of EDO RAM w/error checking and correction												
Docking station												
16 MB of EDO RAM												
1.0 GB hard drive												
Graphics controller w/1MB VRAM												
Type II PCMCIA slots (2)												

Figure 4-2 (Researcher, 1997)

Survey 3

Item	Change	Complexity	Customization	Maintainability	Homogeneity	Consumption	Unit Cost	Documentation	Item Attention	Sources of supply	Criticality	Stability
2.1 GB hot swap ultra wide SCSI drive												
Touchpad												
200MHz processor												
128 MB of EDO RAM												
4.0 GB hard drive												
EIDE controller												
64-bit PCI graphics accelerator w/8MB VRAM												
5.25", front load PC card reader												
Flash BIOS												
SVGA 21" monitor												
16X CD-ROM drive												

Figure 4-3 (Researcher, 1997)

Survey 4

Item	Change	Complexity	Customization	Maintainability	Homogeneity	Consumption	Unit Cost	Documentation	Item Attention	Sources of supply	Criticality	Stability
Soundblaster compatible audio												
64 MB of EDO RAM												
2.0 GB hard drive												
64-bit PCI graphics accelerator w/4MB VRAM												
SVGA 19" monitor												
32 MB of EDO RAM												
1.6 GB hard drive												
64-bit PCI graphics accelerator w/2MB VRAM												
SVGA 17" monitor												
Graphics controller w/2MB VRAM												

Figure 4-4 (Researcher, 1997)

high end server at its highest advertised capability would be higher than midrange and low end servers at their highest advertised capability. This should hold true for the other

configurations across all four groups of surveys. Generally, this was the case as is depicted in Table 4-1. The column entitled "Configuration" represents the bundled systems depicted in Appendix D. The column entitled "Numerical Ranking" refers to the simple arithmetic average of Wenger Model results using all twelve characteristics for similar items in each configuration.

Configuration Rankings

Configuration	Numerical Ranking
IBM compatible high end server	2.60
IBM compatible midrange server	2.55
IBM compatible low end server	2.53
IBM comp. high perf. wrkstation (high end)	2.43
IBM comp. high perf. wrkstation (low end)	2.41
IBM comp. std. appl. wrkstation (high end)	2.49
IBM comp. std. appl. wrkstation (low end)	2.39
Portable (high end)	2.34
Portable (low end)	2.32

Table 4-1 (Researcher, 1997)

The other method would be to determine if items within the same families were ranked as one would intuitively expect. For example, a 16X CD-ROM should receive higher categorical placement than 8X and 4X CD-ROMs. Although this assumption generally holds true, there is some variation. This is not surprising, however, since survey respondents would undoubtedly exhibit some bias in their responses due to unavoidable comparisons with other items on a particular survey. The results are exhibited in Table 4-2. Based on

these two observations, the researcher determined that the data were worth subjecting to more comprehensive analysis.

Family Across Survey Comparisons

Item	Score
16X CD-ROM drive	2.49
8X CD-ROM drive	2.33
4X CD-ROM drive	2.16
200MHz processor w/integrated 512 KB level-2 cache	2.91
200MHz processor w/integrated 256 KB level-2 cache	2.93
200MHz processor	2.91
9.0 GB hot swap ultra wide SCSI drive	2.86
4.0 GB hot swap ultra wide SCSI drive	2.92
2.1 GB hot swap ultra wide SCSI drive	2.86
4.0 GB hard drive	2.63
2.0 GB hard drive	2.46
1.6 GB hard drive	2.42
1.0 GB hard drive	2.30
512 MB of EDO RAM w/error checking and correction	2.63
256 MB of EDO RAM w/error checking and correction	2.74
128 MB of EDO RAM w/error checking and correction	2.64
128 MB of EDO RAM	2.64
64 MB of EDO RAM	2.44
32 MB of EDO RAM	2.36
16 MB of EDO RAM	2.26
SVGA 21" monitor	2.52
SVGA 19" monitor	2.50
SVGA 17" monitor	2.34
SVGA 15" monitor	2.37
10/100BT PCI network interface controller	2.61
10BT network interface controller	2.39
Graphics controller w/2MB VRAM	2.40
Graphics controller w/1MB VRAM	2.59
Enhanced keyboard	2.09
AT keyboard	1.79
Touchpad	2.41
Trackball	1.98
Mouse	1.93
64-bit PCI graphics accelerator w/8MB VRAM	2.88
64-bit PCI graphics accelerator w/4MB VRAM	2.64
64-bit PCI graphics accelerator w/2MB VRAM	2.45

Table 4-2 (Researcher, 1997)

E. DATA COLLECTION

The data were collected over six weeks. As previously mentioned, the researcher opted to obtain the data via a one page numerical survey transmitted via the Internet. To improve the response rate, the researcher first forwarded a small introductory e-mail which explained intent and solicited participation. Hopefully, this would ensure a high response rate. In fact, the researcher expected that nearly 100% of those who said they would participate would do so. This was not the case. Of 150 people who stated they would participate, 72 responded. The researcher determined that this was principally due to two reasons: technological problems and survey interpretation.

1. Technological Problems

The primary technological problem impeding return of surveys was the requirement to encode and decode attachments. The surveys were attached as either an EXCEL or LOTUS 1-2-3 file. Oftentimes, the recipient could not decode the attachment, particularly if they were not using a Netscape browser. In most cases, the researcher believes, that decoding the attachment was within the capability of the recipient. Oftentimes, however, if the file could not be immediately retrieved by the recipient they decided to opt out of participation. On several occasions the

researcher spent inordinate time guiding recipients through the process.

2. Interpretation Problems

The primary interpretation problem related to the manner in which the survey was segmented. Many recipients could not envision assigning rankings to the items listed in the surveys. This, the researcher believes, is directly attributable to the environment in which computer hardware equipment is procured. Although most of the items listed in the survey can be purchased individually (it frequently happens when one upgrades), they are rarely bought that way by Government organizations. Instead, they are purchased as systems--much like the CCR Program Office depicts their available configurations. Many respondents could not envision breaking down the components of a system and considering them on an individual basis. This problem was overcome by engaging potential survey respondents in lengthy dialogue, i.e., numerous back and forth communications explaining the intent of the surveys. Often, the combination of technological and interpretational problems was too difficult to overcome.

F. CONCLUSION

This chapter described how the data were collected for the research effort. The design of the survey was explained, intuitive evaluation of its validity was

described, and two of the problems (technological and interpretation) encountered while conducting the survey were discussed. The next chapter will present the data and analyze the results. Potential conclusions that can be drawn from this analysis will also be discussed. Chapter VI will discuss the implications of the analysis to buying practices used by the CCR Program Office.

V. DATA ANALYSIS

A. INTRODUCTION

Chapter II outlined the basic concepts of taxonomic classification and provided a summary of the development of the Wenger Model for the classification of goods procured by the Federal Government. Chapter III discussed the current environment in which COTS computer hardware equipment is being procured. Its primary thrust concerned the impact of the Clinger-Cohen Act on IT procurement and the process the CCR Program Office uses to acquire computer hardware. Chapter IV discussed the manner in which the researcher collected data, problems with the data collection, and cursory validation of the data itself. This chapter presents and analyzes the collected data.

B. ANALYSIS OVERVIEW

The researcher first decided to analyze the data from a macro perspective and work toward specific analysis of the individual characteristics themselves. This analysis was completed by taking the survey responses and inputting them into separate Microsoft EXCEL 5.0 spreadsheets. After the data were placed in the spreadsheets, the researcher was then able to analyze the results both collectively and on a survey-by-survey basis. Using this technique, the

researcher was able to draw comparisons between the surveys, and draw conclusions about the behavior of characteristics as they related to an item's categorical classification. Ultimately, in order of occurrence, the researcher accomplished the following:

- Determined categorical placement of items based on the Wenger Model.

- Compared the placement of items based on the Wenger Model with placement of items using all twelve original characteristics.

- Developed a different set of characteristics that more closely emulated the results of using all twelve original characteristics.

- Evaluated all characteristics with respect to their impact upon the categorical placement of an item.

The data gathered from surveys are presented in Tables 5-1 through 5-4. Values listed under the characteristics (e.g., C1) represent the average of all responses relating to an item's particular characteristic. The simple arithmetic average of all characteristics (hereafter referred to as the cumulative average) per item is depicted in the second column from the right. The category assignment (far right column) reflects the placement of an item according to its cumulative average. Categories, in ascending order of value, are Simple (1.00-1.80), Basic

(1.81-2.60), Moderate (2.61-3.40), Advanced (3.41-4.20), and Complex (4.21-5.00).

Survey 1 Data

Item	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Cumulative Average	Category
200MHz processor w/integrated 512 KB level-2 cache	4.80	4.30	1.75	1.85	2.05	3.80	3.27	2.55	2.75	2.15	2.85	2.85	2.91	M
512 MB of EDO RAM w/error checking and correction	3.90	3 75	1.75	1.36	2.10	3.95	3.00	1.95	2.30	2.00	2.85	2.65	2 63	M
9.0 GB hot swap ultra wide SCSI drive	4.00	3.95	1.60	2.20	2.25	3.80	3.22	2.45	3.05	2.50	2.36	2.90	2.86	M
4/8 GB internal DAT drive	3.20	3.15	1.30	2.30	2.35	3.80	2.48	2.20	2.95	2.25	2.20	2.36	2.55	B
Dual chan. PCI, int . ultra wide SCSI & disk arr. contr.	3.80	3.85	1.75	1.85	2.64	3.95	2.95	2.40	2.95	2.60	2.30	2.65	2.81	M
Redundant power supply	2.30	2.20	1.10	1.70	1.90	3.70	2.16	1.95	2.75	2.25	2.20	2.10	2.19	B
8X CD-ROM drive	3.76	2.38	1.14	1.81	1.95	3.71	1.90	1.95	2.33	2.14	2.05	2.81	2.33	B
3.5", 1.44MB floppy drive	1.86	1.95	1.10	1.86	1.76	3.76	1.65	1.48	2.38	2.19	2.24	1.95	2.01	B
SVGA contr. w/1024X768 res. w/16 colors & 1mb RAM	3.25	2.90	1.20	1.45	2.05	3.85	2.16	2.05	2.45	2.20	2.45	2.50	2.38	B
SVGA 15" monitor	2.90	2.75	1.20	2.00	1.85	3.75	2.43	2.10	2.45	2.10	2.50	2.36	2.37	B
Type III PCMCIA slot	3.15	2.90	1.50	1.70	1.85	3.95	2.22	2.00	2.70	2.25	2.00	2.35	2.38	B
4X CD-ROM drive	3.14	2.24	1.14	1.76	1.95	3.38	1.75	1.86	2.24	2.10	1.86	2.48	2.16	B
28.8Kbs data/FAX modem	3.33	2.76	1.24	1 67	1.90	3.43	1.95	2.14	2.81	2.24	2.10	2.48	2.34	B
10BT network interface controller	2.85	2.75	1.25	1.70	2.00	3.85	2.16	2.36	2.30	2.45	2.85	2.15	2.39	B
Port replicator	2.94	2.82	1.88	1.82	2.52	3 82	2.25	2.06	2.65	2.46	1.71	2.06	2.42	B

Categories	Characteristics		
S = Simple (1.00-1.80)	C1 - change	C5 - homogeneity	C9 - item attention
B = Basic (1 81-2 60)	C2 - complexity	C6 - consumption	C10 - sources of supply
M = Moderate (2.61-3.4)	C3 - customization	C7 - unit cost	C11 - criticality
A = Advanced (3.41-4.2)	C4 - maintainability	C8 - documentation	C12 - stability
C = Complex (4.21-5.00)			
N = 21			

Table 5-1 (Researcher, 1997)

Survey 2 Data

Item	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Cumulative Average	Category
Enhanced keyboard	1.75	1.94	1.81	1.94	1.88	4.00	1.69	1.69	2.31	1.88	2.25	2.00	2.09	B
Mouse	1.31	1.69	1.81	1.88	1.75	3.81	1.25	1.31	2.13	1.31	2.25	1.94	1.87	B
10/100BT PCI network interface controller	3.07	2.93	2.20	2.00	2.00	3.74	2.73	2.72	2.42	2.13	3.06	2.35	2.61	M
200MHz proc. w/integrated 256 KB level-2 cache	4.08	3.80	2.35	2.35	2.33	3.22	3.21	3.01	3.07	1.99	3.00	2.80	2.93	M
256 MB of EDO RAM w/error checking & correction	3.29	3 28	2.22	2.07	2.33	3.15	3.22	2.14	3.01	2.13	3 14	2.94	2.74	M
4.0 GB hot swap ultra wide SCSI drive	3.86	3.21	2.72	2.28	2.72	3.28	3.14	2.72	3.14	2.00	3.00	3.00	2.92	M
Dual channel PCI, ultra wide SCSI controller	3.72	3.28	2.79	2.21	2.79	3.86	3.07	2.72	3.21	2.07	3.07	2.79	2.97	M
AT keyboard	1.27	1.27	1.79	1.93	1.27	4.08	1.21	1.28	2.13	1.33	2.06	1.87	1.79	S
Trackball	1.38	1.69	1.75	1.94	1.81	4.00	1.69	1.31	2.38	1.81	2.06	1.94	1.98	B
128 MB of EDO RAM w/error checking & correction	3.01	3.08	2.22	2.14	2.26	3.22	3.01	2.14	3.08	2.06	3.07	2.35	2.64	M
Docking station	3.13	2.38	2.06	2.19	3 75	4 13	3.06	2.31	3.06	2.81	2.25	2.75	2.82	M
16 MB of EDO RAM	2.35	2.80	1.87	2.00	2.06	3.15	2.08	1.93	2.73	1.85	2.13	2.15	2.26	B
1.0 GB hard drive	2.06	2.25	2.00	2.19	1.81	3.81	2.00	2.06	2.94	1.94	2.31	2.25	2.30	B
Graphics controller w/1MB VRAM	3.14	3.07	2.20	2.00	2.00	3.81	2.21	2.35	3.01	2.13	2.34	2.87	2.59	B
Type II PCMCIA slots (2)	3.22	2.35	1.94	1.93	1.94	3.35	2.28	2.21	3.00	2.13	3.07	2.74	2.51	B

Categories	Characteristics		
S = Simple (1.00-1.80)	C1 - change	C5 - homogeneity	C9 - item attention
B = Basic (1.81-2.60)	C2 - complexity	C6 - consumption	C10 - sources of supply
M = Moderate (2.61-3.4)	C3 - customization	C7 - unit cost	C11 - criticality
A = Advanced (3.41-4.2)	C4 - maintainability	C8 - documentation	C12 - stability
C = Complex (4.21-5.00)			
N = 16			

Table 5-2 (Researcher, 1997)

Survey 3 Data

Item	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Cumulative Average	Category
2.1 GB hot swap ultra wide SCSI drive	3.86	4.00	1.75	1.92	2.83	3.83	2.59	2.14	2.92	2.31	3.16	3.02	2.86	M
Touchpad	2.81	2.81	1.75	1.80	1.87	3.81	1.88	2.00	2.87	2.25	2.19	2.94	2.41	B
200MHz processor	4.22	4.28	1.27	2.00	2.16	4.11	2.86	2.13	2.70	2.73	3.22	3.28	2.91	M
128 MB of EDO RAM	3.93	3.79	1.79	1.93	1.84	3.33	2.79	1.86	2.31	2.21	2.87	3.08	2.64	M
4.0 GB hard drive	4.00	3.38	1.75	2.13	1.79	3.22	2.19	2.00	2.73	2.19	3.06	3.13	2.63	M
EIDE controller	2.96	3.03	1.24	1.73	2.21	4.26	1.94	1.82	2.27	2.00	2.79	2.27	2.38	B
64-bit PCI graphics accelerator w/8MB VRAM	3.93	4.00	1.93	1.99	2.17	4.02	2.92	2.27	3.08	2.27	2.87	3.08	2.88	M
5.25", front load PC card reader	3.11	2.41	1.86	2.23	2.25	3.42	1.94	1.94	2.33	2.17	2.23	2.72	2.38	B
Flash BIOS	3.08	3.02	2.02	1.78	2.28	4.05	1.70	1.77	2.50	2.36	2.83	2.78	2.51	B
SVGA 21" monitor	3.06	2.94	1.75	1.94	1.80	3.74	2.88	2.06	2.82	2.13	2.19	3.00	2.52	B
16X CD-ROM drive	3.31	3.19	1.69	1.94	1.85	3.81	2.00	1.88	2.37	2.00	2.88	2.94	2.49	B

Categories	Characteristics		
S = Simple (1.00-1.80)	C1 - change	C5 - homogeneity	C9 - item attention
B = Basic (1.81-2.60)	C2 - complexity	C6 - consumption	C10 - sources of supply
M = Moderate (2.61-3.4)	C3 - customization	C7 - unit cost	C11 - criticality
A = Advanced (3.41-4.2)	C4 - maintainability	C8 - documentation	C12 - stability
C = Complex (4.21-5.00)			
N = 16			

Table 5-3 (Researcher, 1997)

Survey 4 Data

Item	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Cumulative Average	Category
Soundblaster compatible audio	3.05	3.24	1.36	1.36	1.94	3.82	1.88	2.06	2.87	2.00	2.05	2.05	2.31	B
64 MB of EDO RAM	3.36	3.81	1.18	1.18	1.94	3.75	2.30	1.75	2.88	2.00	2.88	2.76	2.48	B
2.0 GB hard drive	3.67	3.44	1.61	2.17	2.11	3.33	2.33	2.11	2.67	2.39	3.17	2.00	2.58	B
64-bit PCI graphics accelerator w/4MB VRAM	4.05	3.81	1.30	1.36	2.24	3.81	2.94	2.29	3.05	2.31	2.75	2.29	2.68	M
SVGA 19" monitor	2.50	3.11	1.28	1.94	2.06	3.61	3.28	2.22	3.11	2.33	2.44	2.28	2.51	B
32 MB of EDO RAM	3.36	3.47	1.18	1.18	1.88	3.36	2.00	1.75	2.69	1.94	3.00	2.76	2.38	B
1.6 GB hard drive	3.44	3.06	1.33	2.17	1.89	3.33	2.22	2.06	2.89	2.11	2.44	2.33	2.44	B
64-bit PCI graphics accelerator w/2MB VRAM	3.81	3.24	1.30	1.64	2.12	3.93	2.19	2.29	2.81	2.12	2.17	2.29	2.49	B
SVGA 17" monitor	2.83	3.11	1.28	1.89	1.89	3.44	2.78	2.17	2.78	2.17	2.28	2.33	2.41	B
Graphics controller w/2MB VRAM	3.53	3.23	1.24	1.69	2.06	3.53	2.00	2.24	2.93	2.12	2.36	2.29	2.43	B

Categories	Characteristics		
S = Simple (1.00-1.80)	C1 - change	C5 - homogeneity	C9 - item attention
B = Basic (1.81-2.60)	C2 - complexity	C6 - consumption	C10 - sources of supply
M = Moderate (2.61-3.4)	C3 - customization	C7 - unit cost	C11 - criticality
A = Advanced (3.41-4.2)	C4 - maintainability	C8 - documentation	C12 - stability
C = Complex (4.21-5.00)			
N = 18			

Table 5-4 (Researcher, 1997)

Notice that individual characteristic values can range from Simple to Complex but in the aggregate place the item in a middle category. For example, the first item in Table 5-1 (Survey 1) was assigned characteristic values from Simple (C3 = 1.75) to Complex (C1 = 4.83) yet the item received an Average Value of 2.91 which resulted in

assignment to the Moderate Category. The implication of these relationships will be explored throughout this Chapter.

C. WENGER MODEL RESULTS

An important objective of this study was to determine what the results would be of applying the Wenger Model to computer hardware equipment procured by the Marine Corps' CCR Program Office. As such, the researcher first took data derived from the surveys depicted in Chapter IV and classified the items using only those characteristics present in the Wenger Model. Those characteristics are complexity(C2), customization(C3), maintainability(C4), unit cost(C7), documentation(C8), and item attention(C9).

Prior to conducting this classification, the researcher expected that the results would be similar to those obtained by both Wenger and Prendergast. Wenger tested his model by classifying items that were not homogenous (Wenger, 1990). His study classified many apparently unrelated items like salad dressing and floating dry-docks (Wenger, 1990, p. 56). Unlike Wenger, Prendergast used Wenger's model to classify homogenous items(Prendergast, 1991). His study classified families of goods that bore similarities. These families were P-3 aircraft unique items, food service equipment, and ship/marine equipment. (Prendergast, 1991, pp. 39-41.)

In Prendergast's study, the items showed a reasonably normal distribution with respect to their classification (Prendergast, 1991, p. 79). Of the classified items, each category [simple(1.00-1.80), basic(1.81-2.60), moderate (2.61-3.4), advanced(3.41-4.2), complex(4.21-5.0)] contained at least one item in all categories with the majority of the items being moderate. Wenger's study did not have as normal a distribution as Prendergast's but possessed items in each of the five categories.

The researcher considered that the items in this study were undoubtedly homogenous (computer hardware equipment) but at the same time sufficiently different so that the resulting classification of the items using the Wenger Model would approximate the results obtained by both Wenger and Prendergast, i.e., the items would exhibit a normal distribution and would occupy all categories of the classification scheme. As Table 5-5 shows, this assumption was not entirely correct. This Table depicts the results when using the Wenger Model. All items are included and arranged in descending order. The total Wenger cumulative average, referred to as the Wenger Average, is found in the second column from the right. As one can see, the "Advanced" and "Complex" categories contain none of the items classified by this study.

Wenger Model Results

Item	C2	C3	C4	C7	C8	C9	Wenger Average	Category
200MHz processor w/integrated 256 KB level-2 cache	3.80	2.35	2.35	3.21	3.01	3.07	2.96	Moderate
Dual channel PCI, ultra wide SCSI controller	3.28	2.79	2.21	3 07	2.72	3.21	2.88	Moderate
4 0 GB hot swap ultra wide SCSI drive	3.21	2.72	2.28	3.14	2.72	3.14	2.87	Moderate
9 0 GB hot swap ultra wide SCSI drive	3 95	1.60	2 20	3.22	2.45	3.05	2.74	Moderate
200MHz processor w/integrated 512 KB level-2 cache	4.30	1 75	1.85	3.27	2.55	2.75	2 74	Moderate
64-bit PCI graphics accelerator w/8MB VRAM	4.00	1.93	1.99	2.92	2.27	3.08	2.70	Moderate
256 MB of EDO RAM w/error checking and correction	3.28	2.22	2.07	3.22	2.14	3.01	2.66	Moderate
Dual chan. PCI, integr. ultra wide SCSI & disk array contr.	3.85	1.75	1.85	2.95	2.40	2.95	2.62	Moderate
128 MB of EDO RAM w/error checking and correction	3.08	2.22	2.14	3.01	2.14	3.08	2.61	Moderate
2.1 GB hot swap ultra wide SCSI drive	4.00	1.75	1.92	2.59	2.14	2.92	2.55	Basic
200MHz processor	4.28	1.27	2.00	2 86	2.13	2.70	2.54	Basic
Docking station	2.38	2.06	2.19	3.06	2.31	3.06	2.51	Basic
10/100BT PCI network interface controller	2.93	2.20	2.00	2.73	2.72	2.42	2.50	Basic
SVGA 19" monitor	3.11	1.28	1.94	3.28	2.22	3.11	2.49	Basic
Graphics controller w/1MB VRAM	3.07	2.20	2.00	2.21	2.35	3.01	2.47	Basic
64-bit PCI graphics accelerator w/4MB VRAM	3.81	1.30	1 36	2.94	2.29	3.05	2.46	Basic
128 MB of EDO RAM	3.79	1.79	1.93	2.79	1.86	2.31	2.41	Basic
4/8 GB internal DAT drive	3.15	1.30	2.30	2.48	2.20	2.95	2.40	Basic
SVGA 21" monitor	2.94	1.75	1.94	2.88	2.06	2.82	2.40	Basic
2 0 GB hard drive	3.44	1.61	2.17	2.33	2.11	2.67	2.39	Basic
4.0 GB hard drive	3.38	1.75	2 13	2.19	2.00	2.73	2.36	Basic
512 MB of EDO RAM w/error checking and correction	3.75	1.75	1.36	3.00	1.95	2.30	2.35	Basic
SVGA 17" monitor	3.11	1.28	1.89	2.78	2.17	2.78	2.33	Basic
1 6 GB hard drive	3.06	1.33	2.17	2.22	2.06	2.89	2.29	Basic
Type II PCMCIA slots (2)	2.35	1.94	1.93	2.28	2.21	3.00	2.28	Basic
Port replicator	2.82	1.88	1.82	2.25	2.06	2.65	2.25	Basic
64-bit PCI graphics accelerator w/2MB VRAM	3.24	1.30	1.64	2.19	2.29	2.81	2.24	Basic
1.0 GB hard drive	2.25	2.00	2.19	2.00	2.06	2.94	2.24	Basic
16 MB of EDO RAM	2.80	1.87	2.00	2.08	1.93	2.73	2.23	Basic
Graphics controller w/2MB VRAM	3.23	1.24	1.69	2.00	2.24	2.93	2.22	Basic
Touchpad	2.81	1.75	1.80	1.88	2.00	2.87	2.18	Basic
64 MB of EDO RAM	3.81	1.18	1.18	2.30	1.75	2.88	2.18	Basic
16X CD-ROM drive	3.19	1.69	1.94	2.00	1.88	2.37	2.18	Basic
Type III PCMCIA slot	2.90	1.50	1.70	2.22	2.00	2.70	2.17	Basic
SVGA 15" monitor	2.75	1.20	2.00	2.43	2.10	2.45	2.16	Basic
Flash BIOS	3 02	2.02	1.78	1.70	1.77	2.50	2.13	Basic
Soundblaster compatible audio	3.24	1.36	1.36	1.88	2.06	2.87	2.13	Basic
5.25", front load PC card reader	2.41	1.86	2.23	1.94	1.94	2.33	2.12	Basic
28.8Kbs data/FAX modem	2.76	1.24	1.67	1.95	2.14	2.81	2.09	Basic
10BT network interface controller	2.75	1.25	1.70	2.16	2.36	2.30	2.09	Basic
32 MB of EDO RAM	3.47	1.18	1.18	2.00	1.75	2.69	2.05	Basic
SVGA contr w/1024X768 res. w/16 colors & 1 MB RAM	2.90	1.20	1.45	2.16	2.05	2.45	2.04	Basic
EIDE controller	3.03	1.24	1.73	1.94	1.82	2.27	2.00	Basic
Redundant power supply (internal power supply duplication)	2.20	1.10	1.70	2.16	1.95	2.75	1.98	Basic
8X CD-ROM drive	2.38	1.14	1.81	1.90	1.95	2.33	1.92	Basic
Enhanced keyboard	1.94	1.81	1.94	1.69	1.69	2.31	1 90	Basic
4X CD-ROM drive	2.24	1.14	1.76	1.75	1.86	2.24	1.83	Basic
Trackball	1.69	1.75	1.94	1.69	1.31	2.38	1.79	Simple
3.5", 1.44MB floppy drive	1.95	1.10	1.86	1.65	1.48	2.38	1.73	Simple
Mouse	1.69	1.81	1.88	1.25	1.31	2.13	1.68	Simple
AT keyboard	1.27	1 79	1 93	1.21	1.28	2.13	1.60	Simple

Table 5-5 (Researcher, 1997)

It is clear that the items, when classified using the Wenger Model characteristics, do not fall within all of the available categories. In fact, they are clustered within the lower half of the spectrum. They do, however, exhibit a close approximation to a normal distribution. If the results are segmented into five equal categories, the distribution is as depicted in Table 5-6.

Wenger Distribution

Category	Range	Items in Range
Mid to Low Moderate	2.96-2.688	6
Low Moderate to High Basic	2.687-2.416	10
High to Mid Basic	2.415-2.144	19
Mid to Low Basic	2.144-1.872	11
Low Basic to High Simple	1.871-1.60	5
Total	2.96-1.60	51

Table 5-6 (Researcher, 1997)

The lack of variability with respect to the categorical scores was surprising to the researcher. There was an expectation that some of the items would be categorized as advanced or complex. The researcher believed that the principal reason for the lack of variability might be attributable to the types of characteristics present in the

Wenger Model. Of the six characteristics, (complexity-C2, customization-C3, maintainability-C4, unit cost-C7, documentation-C8, and item attention-C9)the researcher felt that all but complexity and unit cost might be contributing both to the generally low scores and the lack of variability among the items.

The reasoning behind this is simple. If one reviews the definitions of the characteristics contained in Appendix A, it becomes intuitively clear that COTS computer equipment might show little variability with respect to customization (C3), maintainability (C4), documentation (C8), and item attention (C9) because:

- Buyers have little ability to influence the design of commercial products, i.e., little customization.
- Computer equipment is traditionally maintenance free with respect to the hardware. Maintenance is usually a factor of software problems, thus, one would expect little maintenance requirements.
- The documentation associated with buying COTS computer equipment probably amounts to little more than the standard paperwork that all consumers receive when they purchase items of this type, therefore, there would be minimal documentation requirements.
- There is little item attention because the types of equipment classified in this study are traditionally purchased in large volumes.

If the above suppositions are true then the characteristics contributing to low scores and low

variability should have comparatively lower ranges and average scores with respect to complexity and unit cost. Furthermore, they might display the same behavior with respect to some of the remaining twelve characteristics. As Table 5-7 shows, this is true. Wenger characteristics are shaded and all characteristics are arranged in descending order with respect to their Magnitude of Range.

Range & Average Score Comparisons

Characteristic	Magnitude of Range	Average Score
Change(C1)	3.53	3.17
Complexity(C2)	3.03	3.02
Homogeneity(C5)	2.48	2.10
Unit Cost(C7)	2.07	2.37
Documentation(C8)	1.73	2.08
Customization(C3)	1.70	1.66
Criticality(C11)	1.51	2.54
Sources(C10)	1.50	2.15
Stability(C12)	1.42	2.53
Maintainability(C4)	1.17	1.88
Consumption(C6)	1.11	3.70
Item Attention(C9)	1.08	2.71

Table 5-7 (Researcher, 1997)

The above reasoning may partially explain the results specific to the Wenger Model. The interesting Magnitudes of Range and Average Scores of the remaining characteristics,

however, implies that insight could be gained by comparing the results when using the Wenger Model and when using all twelve characteristics. The next section discusses this comparison and shows that the Wenger Model results are different from the results obtained when using all twelve characteristics. This suggests that characteristics other than those used in the Wenger Model affect the categorical placement of COTS computer hardware equipment.

D. WENGER MODEL COMPARED TO ALL CHARACTERISTICS

The researcher expected that a comparison of the Wenger Model results with those that considered all twelve characteristics should show little variation, i.e., the items in both results would closely approximate each other with respect to categorical placement and numerical value. Table 5-8 gives a comparison of the results. It is arranged in descending order with respect to the results obtained using the Wenger Model. The differences between the two results are depicted to the far right. As the Table shows, the above expectation was not true. For example, of fifty-one items, fifteen showed a shift of 0.26 or greater. This is significant because it means that 29% of the items moved through more than a third of a category.

Overall, the results showed a normal distribution for the total characteristic results. The total magnitude of their range was less than the Wenger Model results (1.18

Study Characteristics versus Wenger Model

Item	Wenger Average	Category	Total Average	Category	Change
200MHz processor w/integrated 256 KB level-2 cache	2.96	Moderate	2.93	Moderate	-0.03
Dual channel PCI, ultra wide SCSI controller	2.88	Moderate	2.97	Moderate	0.09
4.0 GB hot swap ultra wide SCSI drive	2.87	Moderate	2.92	Moderate	0.05
9.0 GB hot swap ultra wide SCSI drive	2.74	Moderate	2.86	Moderate	0.11
200MHz processor w/integrated 512 KB level-2 cache	2.74	Moderate	2.91	Moderate	0.17
64-bit PCI graphics accelerator w/8MB VRAM	2.70	Moderate	2.88	Moderate	0.18
256 MB of EDO RAM w/error checking and correction	2.66	Moderate	2.74	Moderate	0.09
Dual chan. PCI, integ ultra wide SCSI & disk array contr.	2.62	Moderate	2.81	Moderate	0.18
128 MB of EDO RAM w/error checking and correction	2.61	Moderate	2.64	Moderate	0.03
2.1 GB hot swap ultra wide SCSI drive	2.55	Basic	2.86	Moderate	0.31
200MHz processor	2.54	Basic	2.91	Moderate	0.37
Docking station	2.51	Basic	2.82	Moderate	0.31
10/100BT PCI network interface controller	2.50	Basic	2.61	Moderate	0.11
SVGA 19" monitor	2.49	Basic	2.51	Basic	0.02
Graphics controller w/1MB VRAM	2.47	Basic	2.59	Basic	0.12
64-bit PCI graphics accelerator w/4MB VRAM	2.46	Basic	2.68	Moderate	0.22
128 MB of EDO RAM	2.41	Basic	2.64	Moderate	0.23
4/8 GB internal DAT drive	2.40	Basic	2.55	Basic	0.15
SVGA 21" monitor	2.40	Basic	2.52	Basic	0.13
2.0 GB hard drive	2.39	Basic	2.58	Basic	0.19
4.0 GB hard drive	2.36	Basic	2.63	Moderate	0.27
512 MB of EDO RAM w/error checking and correction	2.35	Basic	2.63	Moderate	0.28
SVGA 17" monitor	2.33	Basic	2.41	Basic	0.08
1.6 GB hard drive	2.29	Basic	2.44	Basic	0.15
Type II PCMCIA slots (2)	2.28	Basic	2.51	Basic	0.23
Port replicator	2.25	Basic	2.42	Basic	0.17
64-bit PCI graphics accelerator w/2MB VRAM	2.24	Basic	2.49	Basic	0.25
1.0 GB hard drive	2.24	Basic	2.30	Basic	0.06
16 MB of EDO RAM	2.23	Basic	2.26	Basic	0.02
Graphics controller w/2MB VRAM	2.22	Basic	2.43	Basic	0.21
Touchpad	2.18	Basic	2.41	Basic	0.23
64 MB of EDO RAM	2.18	Basic	2.48	Basic	0.30
16X CD-ROM drive	2.18	Basic	2.49	Basic	0.31
Type III PCMCIA slot	2.17	Basic	2.38	Basic	0.21
SVGA 15" monitor	2.16	Basic	2.37	Basic	0.21
Flash BIOS	2.13	Basic	2.51	Basic	0.38
Soundblaster compatible audio	2.13	Basic	2.31	Basic	0.18
5.25", front load PC card reader	2.12	Basic	2.38	Basic	0.27
28.8Kbs data/FAX modem	2.09	Basic	2.34	Basic	0.24
10BT network interface controller	2.09	Basic	2.39	Basic	0.30
32 MB of EDO RAM	2.05	Basic	2.38	Basic	0.33
SVGA contr. w/1024X768 res. w/16 colors & 1 MB RAM	2.04	Basic	2.38	Basic	0.34
EIDE controller	2.00	Basic	2.38	Basic	0.37
Redundant power supply (internal power supply duplication)	1.98	Basic	2.19	Basic	0.22
8X CD-ROM drive	1.92	Basic	2.33	Basic	0.41
Enhanced keyboard	1.90	Basic	2.09	Basic	0.20
4X CD-ROM drive	1.83	Basic	2.16	Basic	0.33
Trackball	1.79	Simple	1.98	Basic	0.19
3.5", 1.44MB floppy drive	1.73	Simple	2.01	Basic	0.28
Mouse	1.68	Simple	1.87	Basic	0.19
AT keyboard	1.60	Simple	1.79	Simple	0.19

Table 5-8 (Researcher, 1997)

versus 1.36). This value allows for little separation among items since the range per category of the Wenger Model is 0.79. Classifying the items using all twelve characteristics instead of six had the effect of raising the average categorical value of all items save one(200MHz processor w/integrated 256 KB of cache). This resulted in an upward migration of some items from the "Basic" category to "Moderate" and from the "Simple" category to "Basic". The uppermost limit of the values, however, was bounded. This suggests that some of the Wenger Model characteristics and potentially some of the remaining six characteristics had the effect of pressuring an item toward the lower end of the categorical spectrum.

After reviewing these results, the researcher decided to determine if there was a different mix of characteristics that more closely matched the results of using all characteristics.

E. REVISED MODEL (REDUCTION)

One structural aspect Wenger discovered in the development of his model was that the removal of six of the twelve characteristics would have limited impact on the categorical and value ranking of the classified items (Wenger, 1990). His analysis showed that this was true and was subsequently validated by Prendergast (Prendergast,

1991). A benefit of Wenger's reduction of characteristics was that it made the classification process much simpler. He summarized this benefit by explaining that reducing the characteristics by 50% should make classifying a good easier but still retain the original classification results provided when using all characteristics(Wenger, 1990, p. 82).

In this portion of the analysis, and assuming that the results of using all characteristics was sound, the researcher sought to both reduce the number of characteristics used for classification and still closely replicate the results obtained from the original analysis.

A principal basis for removal of characteristics in Wenger's analysis was to iteratively eliminate those characteristics whose mean varied little across clusters (Wenger, 1990, p. 78). Unlike Wenger and Prendergast, the researcher did not conduct a cluster analysis to aid in the characteristic reduction process. Without using this tool, the researcher approached iteratively eliminating characteristics based on the cumulative impact their removal had on the values of all items in all surveys. Starting with twelve characteristics, the one that had the lowest cumulative impact was removed. This process was then repeated with eleven through three characteristics. Throughout the process, all eliminated characteristics were

substituted back in at each iteration to test for sensitivity.

Additionally, the researcher decided that removal of a characteristic could not change a value by more than 0.13. The basis for this decision lies in the realization that an item with a value of 2.60 (upper basic) differs little from an item with a value of 2.61 (lower moderate). In this case, by assigning labels of "Basic" and "Moderate" to the items one would not benefit from the understanding that there was virtually no difference between them. Wenger realized this and suggested that each category should be segmented into three equal ranges and a "+", "0", or "-" assigned to the item. A "+" would indicate a value that fell in the upper end of a category, etc. (Wenger, 1990, p. 88) Given this segmentation, which equates to three equal ranges of 0.26 per category, the researcher decided that if the removal of a characteristic did not change a value by more than 0.13 than one could be assured that it would remain within the segmented categories suggested by Wenger.

By going through this process, the researcher hoped to derive a set of characteristics that remained consistent with the results obtained when using all twelve characteristics. Optimally, there should be minimal value changes and the changes should fall within a 0.13 range. By going through the previously described process, the

researcher found that one could eliminate five characteristics (unit cost-C7, item attention-C9, sources of supply-C10, criticality-C11, stability-C12) and closely replicate the results when using twelve characteristics.

The researcher conducted elimination with replacement down to three characteristics but found that eliminating six or more characteristics violated the researcher's parameter that no item's value should change more than 0.13. The results of this analysis are contained in Table 5-9. This Table contains the values obtained when using twelve characteristics, the values obtained when using the seven retained characteristics, and the difference between the two results. Items are listed in descending order respective to their values obtained when using twelve characteristics.

Ultimately, the researcher found that those characteristics retained for classification purposes were: change(C1), complexity(C2), customization(C3), maintainability(C4), homogeneity(C5), consumption(C6), and documentation(C8). The process used by the researcher satisfied the constraints and was consistent across all four surveys. If one assumes that combining all twelve characteristics is a viable means for classifying computer hardware equipment then the retention of the characteristics noted above would make the classification process easier.

Original versus New Comparison

Item	Original Average	Category	New Average	Category	Change
Dual channel PCI, ultra wide SCSI controller	2.97	Moderate	3.05	Moderate	0.09
200MHz processor w/integrated 256 KB level-2 cache	2.93	Moderate	3.02	Moderate	0.09
4.0 GB hot swap ultra wide SCSI drive	2.92	Moderate	2.97	Moderate	0.05
200MHz processor w/integrated 512 KB level-2 cache	2.91	Moderate	3.01	Moderate	0.10
200MHz processor	2.91	Moderate	2.88	Moderate	-0.03
64-bit PCI graphics accelerator w/8MB VRAM	2.88	Moderate	2.90	Moderate	0.02
2.1 GB hot swap ultra wide SCSI drive	2.86	Moderate	2.90	Moderate	0.04
9.0 GB hot swap ultra wide SCSI drive	2.86	Moderate	2.89	Moderate	0.04
Docking station	2.82	Moderate	2.85	Moderate	0.03
Dual chan. PCI, int.. ultra wide SCSI & disk arr. contr.	2.81	Moderate	2.89	Moderate	0.08
256 MB of EDO RAM w/error checking and correction	2.74	Moderate	2.64	Moderate	-0.10
64-bit PCI graphics accelerator w/4MB VRAM	2.68	Moderate	2.70	Moderate	0.01
128 MB of EDO RAM	2.64	Moderate	2.64	Moderate	0.00
128 MB of EDO RAM w/error checking and correction	2.64	Moderate	2.58	Basic	-0.06
512 MB of EDO RAM w/error checking and correction	2.63	Moderate	2.68	Moderate	0.05
4.0 GB hard drive	2.63	Moderate	2.61	Moderate	-0.02
10/100BT PCI network interface controller	2.61	Moderate	2.67	Moderate	0.05
Graphics controller w/1MB VRAM	2.59	Basic	2.65	Moderate	0.06
2.0 GB hard drive	2.58	Basic	2.63	Moderate	0.05
4/8 GB internal DAT drive	2.55	Basic	2.62	Moderate	0.07
SVGA 21" monitor	2.52	Basic	2.47	Basic	-0.05
SVGA 19" monitor	2.51	Basic	2.39	Basic	-0.13
Flash BIOS	2.51	Basic	2.57	Basic	0.06
Type II PCMCIA slots (2)	2.51	Basic	2.42	Basic	-0.09
64-bit PCI graphics accelerator w/2MB VRAM	2.49	Basic	2.62	Moderate	0.13
16X CD-ROM drive	2.49	Basic	2.52	Basic	0.04
64 MB of EDO RAM	2.48	Basic	2.42	Basic	-0.06
1.6 GB hard drive	2.44	Basic	2.47	Basic	0.03
Graphics controller w/2MB VRAM	2.43	Basic	2.50	Basic	0.07
Port replicator	2.42	Basic	2.55	Basic	0.13
Touchpad	2.41	Basic	2.41	Basic	-0.01
SVGA 17" monitor	2.41	Basic	2.37	Basic	-0.04
10BT network interface controller	2.39	Basic	2.39	Basic	0.00
5.25", front load PC card reader	2.38	Basic	2.46	Basic	0.08
32 MB of EDO RAM	2.38	Basic	2.31	Basic	-0.07
Type III PCMCIA slot	2.38	Basic	2.43	Basic	0.05
SVGA contr. w/1024X768 res. w/16 colors & 1mb RAM	2.38	Basic	2.39	Basic	0.02
EIDE controller	2.38	Basic	2.46	Basic	0.09
SVGA 15" monitor	2.37	Basic	2.36	Basic	0.00
28.8Kbs data/FAX modem	2.34	Basic	2.35	Basic	0.02
8X CD-ROM drive	2.33	Basic	2.39	Basic	0.06
Soundblaster compatible audio	2.31	Basic	2.40	Basic	0.10
1.0 GB hard drive	2.30	Basic	2.31	Basic	0.01
16 MB of EDO RAM	2.26	Basic	2.31	Basic	0.05
Redundant power supply	2.19	Basic	2.12	Basic	-0.07
4X CD-ROM drive	2.16	Basic	2.21	Basic	0.05
Enhanced keyboard	2.09	Basic	2.14	Basic	0.05
3.5", 1.44MB floppy drive	2.01	Basic	1.97	Basic	-0.05
Trackball	1.98	Basic	1.98	Basic	0.00
Mouse	1.87	Basic	1.94	Basic	0.07
AT keyboard	1.79	Simple	1.84	Basic	0.05

Table 5-9 (Researcher, 1997)

There are, however, potential problems associated with this revised set of characteristics. First, there still is little variability among the items. All items are categorized as either "basic" or low "moderate". Second, the model still retains characteristics that the researcher considered as having limited impact on classification of COTS computer equipment, namely customization(C6), maintainability(C4), and documentation(C8). Third, the methodology used to eliminate characteristics might be doing nothing more than substituting one characteristic for another with no regard for the actual impact a characteristic has on an item's classification. With this in mind, the researcher decided to explore the behavior of the characteristics in greater depth to determine if additional insight could be gained that would aid the procurement process.

F. SPECIFIC CHARACTERISTIC ANALYSIS

To accomplish this, the researcher felt that an analysis of the behavior of the characteristics must be conducted. The researcher decided that this analysis would be comprised of four steps. The first step would be to look more closely at the magnitude of range displayed by each characteristic. Second would be to evaluate the impact a characteristic had on an item's overall ranking. Third

would be to look at the behavior of the characteristic's standard deviations. Fourth would be to determine if any characteristics displayed a linear relationship to the overall numerical averages.

The researcher found it difficult to discern trends for the first three steps when one looked at each characteristic per each item. Consequently, the researcher decided to group the characteristics into five equal groups consisting of ten items per group with the middle group having eleven items. The ten items having the highest Cumulative Average when using twelve characteristics were grouped together. This process continued until the items having the ten lowest Cumulative Average were grouped together.

1. Comparison of Magnitudes of Range

A method Wenger used as a basis for characteristic removal was to compare means across various clusters. If a characteristic displayed a wide range across clusters then one could deduce that the characteristic made a significant contribution to an item's categorization. Conversely, if a characteristic did not display a wide range across clusters then the characteristic's impact on an item's categorization might be minimal. (Wenger, 1990, p.78)

The researcher deduced that the same principle of range comparison could be applied to the data obtained in this study. Toward this end, the researcher took the already

divided groups and computed the mean of each characteristic in each group and then determined the magnitude of range of the means for all groups. From this, the researcher believed that one could gain insight into which characteristics had an impact on the differentiation of items. Naturally, all characteristics affect an item's categorical placement. The researcher believed, however, that this analysis might show which characteristics contributed most significantly to their differentiation. Table 5-10 depicts the means of each characteristic per group. The magnitude of ranges of these means is shown below them.

Magnitude of Ranges

Item Groupings	C1 Means	C2 Means	C3 Means	C4 Means	C5 Means	C6 Means	C7 Means	C8 Means	C9 Means	C10 Means	C11 Means	C12 Means	Average Mean
1	3.96	3.73	1.97	2.07	2.55	3.80	3.04	2.47	2.99	2.35	2.78	2.90	2.88
2	3.51	3.35	1.81	1.93	2.08	3.55	2.69	2.17	2.78	2.15	2.81	2.61	2.62
3	3.19	3.06	1.57	1.80	2.04	3.70	2.28	2.05	2.80	2.19	2.45	2.56	2.47
4	3.16	2.84	1.30	1.73	1.97	3.70	2.15	2.04	2.52	2.18	2.41	2.47	2.37
5	2.09	2.14	1.53	1.84	1.82	3.74	1.75	1.70	2.49	1.89	2.14	2.08	2.10
Total Mean	3.18	3.02	1.64	1.88	2.09	3.70	2.38	2.09	2.71	2.15	2.52	2.52	2.49
Magnitude of Range	1.87	1.59	0.67	0.34	0.73	0.25	1.29	0.77	0.50	0.46	0.67	0.82	

Characteristics					
C1	- change	C5	- homogeneity	C9	- item attention
C2	- complexity	C6	- consumption	C10	- sources of supply
C3	- customization	C7	- unit cost	C11	- criticality
C4	- maintainability	C8	- documentation	C12	- stability

Table 5-10 (Researcher, 1997)

Some interesting characteristic behaviors can be derived by analyzing these data. Some conclusions that can be drawn are:

- The displayed magnitudes of range indicate that change(C1), complexity(C2), and unit cost(C7) play a much greater role in the placement of an item across the categorical spectrum than do the other characteristics (all three had magnitudes exceeding 1.00).

- The low means and small magnitudes of range of customization(C3) and maintainability(C4) indicate that, despite the item, respondents uniformly consider these characteristics to have limited impact on an item's categorical complexity.

- The high mean and small magnitude of range of consumption(C6) indicate that, despite the item, respondents uniformly consider this characteristic to have significant impact on an item's categorical complexity.

- All characteristics except change(C1), complexity(C2), and unit cost(C7) do little to differentiate items. This is because these characteristics have comparatively large magnitudes of range.

Referring back to Table 5-9 and the discussion surrounding it, the researcher found that one could classify COTS computer hardware equipment by using the characteristics of change(C1), complexity(C2), customization(C3), maintainability(C4), homogeneity(C5), consumption(C6), and documentation(C8). The data contained in Table 5-10, however, potentially suggest that most of these characteristics might not have to be used when classifying this family of goods. How can one, however, justify ignoring characteristics like customization(C3), maintainability(C4) and consumption(C6) when they have significant impact on the categorical placement of an item?

A potential justification is that, despite their contribution to the placement of an item, these characteristics do little to differentiate items. For example, it would not matter if consumption had a mean of 3.70 (its current value) or 1.00. All items would still have the same basic ranking with respect to each other but would uniformly shift downward. Not surprisingly, as is the case here, if the majority of characteristics that have low ranges also have low means then the overall value of an item will be artificially low. Furthermore, the items will be compressed into a smaller range thereby reducing one's ability to discern differences between them. The researcher feels that the characteristics used in the revised Wenger

Model are acceptable, however, the researcher also feels that this particular area is ripe for further research and clarification.

2. Characteristic Impact

Another method used by the researcher to gain insight into the behavior of characteristics was to evaluate the impact a characteristic had on an item's categorical value. This analysis was conducted by comparing the categorical average value of all characteristics with the categorical average value of eleven characteristics (the analyzed characteristic being the missing twelfth). Understandably, this would inevitably yield small results, but one should be able to determine if particular characteristics exhibited upward or downward trends with respect to their impact on an item's categorical value. The results of this analysis are depicted in Table 5-11. Numbers listed under the characteristics indicate the impact of their removal. For example, the removal of change(C1) from Group 1 had the effect of lowering the categorical value of the items in the group by 0.09. The row entitled "Trend" indicates the characteristic's impact on the categorical ranking of an item as items move from their highest ranking to their lowest. For example, change(C1) has less and less impact on an item's categorical ranking as the rankings decrease, thus, it exhibits a downward trend.

Impact of Characteristic Removal on Average Values

Group	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
1	-0.09	-0.07	0.07	0.07	0.03	-0.08	-0.01	0.04	-0.01	0.06	0.00	0.00
2	-0.08	-0.07	0.07	0.06	0.05	-0.08	-0.01	0.04	-0.01	0.04	-0.02	0.00
3	-0.07	-0.05	0.08	0.06	0.04	-0.11	0.02	0.04	-0.03	0.03	0.00	-0.01
4	-0.06	-0.05	0.09	0.06	0.04	-0.12	0.02	0.03	-0.02	0.02	-0.01	-0.01
5	-0.01	0.00	0.05	0.02	0.03	-0.15	0.03	0.04	-0.03	0.02	0.00	0.00
All Items	-0.06	-0.05	0.07	0.05	0.04	-0.11	0.01	0.04	-0.02	0.03	-0.01	0.00
Trend	down	down	none	up	none	up	down	none	none	up	none	none

Characteristics

C1	- change	C5	- homogeneity	C9	- item attention
C2	- complexity	C6	- consumption	C10	- sources of supply
C3	- customization	C7	- unit cost	C11	- criticality
C4	- maintainability	C8	- documentation	C12	- stability

Table 5-11 (Researcher, 1997)

Some conclusions the researcher drew from the above data are:

- Overall, consumption (C6) has the greatest impact on the categorical placement of an item. Furthermore, as an item decreases in categorical ranking (Complex to Simple), the impact of consumption increases(exhibiting the "up" trend in Table 5-11). This is not surprising. Referring back to Table 5-10, one finds that consumption possesses both the lowest range and highest mean. Relative to the other characteristics, consumption changes little as one moves from Group 1 through Group 5. Since its mean (3.70) is comparatively high, its influence on an item's placement will increase as an item's categorical placement decreases. The same argument is true for maintainability(C4) and sources of

supply(C10). The difference, however, is that these latter two characteristics have relatively low means among the other characteristics.

- In contrast to this upward trend, the impact of change(C1), complexity(C2), and unit cost(C7) decreases as categorical placement decreases. Once again, this is not surprising. Table 5-11 shows that each of these characteristics had relatively broad ranges. If more characteristics had similar broad ranges, then these three characteristics would have less impact.

- Based on the data in Table 5-11, it is easy to segregate characteristics based on their overall impact (positive: consumption, change, complexity, item attention; neutral: stability; negative: customization, maintainability, homogeneity, documentation, sources of supply, unit cost).

In some respects, however, the last point is only useful to gain a broader understanding of all COTS computer hardware. The more crucial question to ask is why characteristics behave as they do? When one considers the data in both Tables 5-10 and 5-11 one can conclude that

characteristics generally have a strong impact on an item's high or low-end categorical placement for two reasons:

- The characteristic has a wide range (change, complexity, unit cost).

- The characteristic has a low range and the mean is at the upper or lower end of the categorical spectrum (consumption, maintainability).

3. Characteristic Deviations

Another method the researcher chose to gain greater insight into the behavior of characteristics was to look at the standard deviation of the responses with respect to an individual item's characteristics. For purposes of this analysis, the researcher chose to remain consistent and evaluate the deviations in each group. The data obtained from this analysis are contained in Table 5-12.

Characteristic Deviations

Group	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Group Avg.
1	0.73	0.88	0.90	0.69	0.95	0.75	0.83	0.84	0.75	0.71	0.78	0.82	0.80
2	0.90	0.89	0.82	0.71	0.87	0.85	0.89	0.70	0.85	0.73	0.84	0.85	0.83
3	0.91	0.85	0.74	0.68	0.81	0.93	0.86	0.62	0.77	0.67	0.86	0.85	0.80
4	0.88	0.82	0.53	0.63	0.88	0.88	0.73	0.58	0.85	0.79	0.91	0.89	0.78
5	1.05	0.87	0.65	0.67	0.95	0.85	0.73	0.64	1.02	0.80	0.88	0.86	0.83
Total Avg	0.80	0.75	0.67	0.65	0.84	0.82	0.74	0.64	0.82	0.70	0.79	0.81	
# > 1.00	7	3	3	2	8	3	2	1	10	2	6	5	
% > 1.00	14%	6%	6%	4%	16%	6%	4%	2%	20%	4%	12%	10%	

Characteristics

C1 - change	C5 - homogeneity	C9 - item attention
C2 - complexity	C6 - consumption	C10 - sources of supply
C3 - customization	C7 - unit cost	C11 - criticality
C4 - maintainability	C8 - documentation	C12 - stability

Table 5-12 (Researcher, 1997)

Among the techniques used by the researcher to gain insight into a characteristic's behavior, the analysis of standard deviation proved difficult. Despite numerous attempts to look at deviation from "different angles" the researcher could not draw any substantive conclusions. No discernable pattern emerged when deviations were considered on a family-by-family basis (processors, monitors, etc.), grouping of the deviations themselves (0.5-0.6,0.7-0.8,etc.), and when considering their relationship to the items as the categorical value of items decreased.

The only reasonable conclusion the researcher could draw was the possibility that there is a relationship between some families and the age of the technology. For example, deviation decreased as technological capability increased when compared to RAM, CD-ROMs, and graphic accelerators. Conversely, deviation decreased as technological capability decreased when compared to processors and hot swap drives. The researcher, however, was uncomfortable with this conclusion because there were not enough members of a particular family to rule out chance as the reason for this observation.

Concerning the data contained in Table 5-12, the researcher can make some potentially beneficial observations. These observations are:

- The deviations for customization(C3) and item attention(C9) generally decrease as an item's categorical ranking decreases. In other words (at least for these characteristics) respondents' collective perception of the characteristics became more uniform as items became more categorically simple.

- The deviation for criticality(C11) generally increases as an item's categorical value decreases. The respondents' collective perception became less uniform as items became more categorically simple.

- The three characteristics exhibiting the lowest average deviations were documentation(C8), maintainability(C4), and customization(C3). Because of the nature of these characteristics, this might indicate that (regardless of the item) respondents view these characteristics as having essentially the same values across the entire family of COTS computer hardware equipment.

The researcher believes that there is little insight to be gained from analyzing the deviations as has been done above. If one looks at the deviations from a broader perspective, however, the researcher believes that there is

some value to this process as it relates to improving procurement processes.

Initially, the researcher was disturbed by the high variability of responses when one looked at the deviations associated with one characteristic per item. The deviations in this study were similar to results obtained by Wenger (Wenger, 1990, p.120). Wenger's study, however, contained disparate items. Intuitively, it is easier to explain his results because respondents cannot avoid comparing the items. In this study, the items were homogenous. Even though the respondents would still compare items, they should naturally rank them. This, the researcher believes, would have the effect of decreasing the variance in the responses. Why then are the deviations higher than the researcher expected?

First, without question, the scaling (1-5) contributed to the results. If one had a sample of 50 and respondents evenly split between assigning scores of either 3 or 4, then the deviation for that characteristic for that item would be 0.51. Clearly, unless the responses were nearly identical, the scaling contributes to the deviations of the scores.

Another possibility is that COTS computer hardware equipment is not nearly as homogenous as one would expect. Maybe processors, CD-ROMs, monitors, and graphics

controllers (to name a few) are distinct items that bear little similarity to each other.

A third possibility is that computer hardware components are perceived as little more than piece parts. Since the Government generally buys systems, it is both conceivable and understandable that those involved in the procurement of hardware equipment might perceive these components as nothing more than capacitors, diodes or screws.

The fourth possibility, and the one the researcher supports, attributes the high deviations to lack of common knowledge among all the participants in the procurement of COTS computer hardware equipment. This is not to say that requirements personnel, buyers, and users, etc., do not have substantial knowledge about the item being procured. It implies, however, that the knowledge is different. The researcher believes that this is enormously important to the procurement process in an era when the Government is being driven to achieve both effectiveness and efficiency.

4. Characteristic Relationships to Categorical Values

A final method the researcher chose to analyze the behavior of the characteristics was to determine if there were any linear relationships between the characteristics and the categorical rankings. Was the outcome (categorical ranking) dependent on the variable (a characteristic)?

If any strong linear relationships could be established, then these relationships might be important. For example, Wenger used six characteristics to classify items. The small number of characteristics simplified the classification process. If, however, one or two characteristics displayed strong linear relationships, then they could be used to predict an item's categorical ranking. This would further simplify the classification process.

With this in mind, the researcher sought to determine if any characteristics displayed strong linear relationships to categorical rankings of items. The parameters of strength were that the R^2 statistic must exceed 0.50 (indicates a relatively strong relationship) and that the t-statistic must be greater than 2.0 (indicates statistical significance). The results of this analysis when using all twelve characteristics are shown in Table 5-13. Only those items meeting the parameters are depicted.

Linear Statistics with 12 Characteristics

	C1	C2	C7	C8	C12
R2 stat	0.71	0.69	0.74	0.65	0.52
t-stat	16.84	14.84	16.64	8.01	6.28

Characteristics

C1:	change	C7:	unit cost	C12:	stability
C2:	complexity	C8:	documentation		

Table 5-13(Researcher, 1997)

The above data, computed at a 95% confidence level, suggest that change(C1), complexity(C2), unit cost(C7), documentation(C8), and stability(C12) have reasonably strong linear relationships with the categorical values. If the characteristics are useful for categorizing computer hardware equipment, then one could use the above characteristics to predict an item's categorical value.

Of the characteristics that showed a linear relationship to an item's categorical ranking, change(C1), complexity(C2) and documentation(C8) were ones that were retained after the researcher had modified the Wenger Model. To further test the applicability of these linear relationships, the researcher decided to determine if these characteristics still retained their strong linear relationships in the revised model. As Table 5-14 shows, the linear relationships were still useful.

Linear Statistics with Revised Characteristics

	C1	C2	C8
R2 stat	0.73	0.66	0.67
t-stat	11.46	9.8	9.89
	Characteristics		
C1: change		C8: domcumentation	
C2: complexity			

Table 5-14 (Researcher, 1997)

G. CONCLUSION

This chapter discussed the results obtained when using the Wenger Model to classify computer hardware equipment.

It provided an alternative set of seven characteristics that closely replicated the survey results. It then explored the behavior of the characteristics by discussing their magnitudes of range, means and standard deviations. It ended by looking at those characteristics that had strong linear relationships to an item's categorical ranking.

The next chapter will discuss how this analysis can benefit those who procure COTS computer hardware equipment. In particular, it concentrates on the practices employed by the Marine Corps and its CCR Program Office.

VI. BENEFITS OF THE WENGER MODEL

A. INTRODUCTION

As discussed in Chapter III, the Clinger-Cohen Act requires that the focus of IT procurement must be investment oriented. In particular, "Agencies need to develop quantitative criteria to use for comparing and prioritizing alternative information system projects." (Sochon, 1997, p.6) Given the large number of IT contracts available as a result of the Clinger-Cohen Act, and given that industry generally prefers to sell COTS IT equipment as complete systems rather than by component, the researcher feels that the Wenger Model can provide a tool which the CCR Program Office can use for comparing and prioritizing these IT investment alternatives.

This Chapter discusses how the Wenger Model and its results can aid the IT procurement process. Additionally, it discusses other aspects of the Wenger Model results that the researcher feels are potentially important to successful long-term COTS IT procurement.

B. COST-BENEFIT ANALYSIS

Currently, the primary roles of the CCR Program Office requirements personnel are to: 1) validate needs of organizations requesting new IT equipment, and 2) to ensure

that the identified solutions meet minimum Marine Corps Hardware Configuration Standards. Although these roles are important, the researcher believes that the CCR Program Office requirements personnel can have a much more significant impact on the quality of IT investments if it would involve the user in some type of cost-benefit analysis.

The Wenger Model results could have strong implications for the decisionmaking process the user employs to arrive at IT investment decisions. If, as Chapter V suggests, certain characteristics help to categorically differentiate items, then CCR and users can use the knowledge obtained from this differentiation to help formulate their decisions. The process this team could use to arrive at a decision might consist of: 1) generating scenarios relating to an IT procurement, 2) identifying the costs and benefits of the scenarios, 3) using the Wenger Model to classifying the IT procurement 4) estimating the probability of a scenario's occurrence, 5) generating cost-benefit streams, and 6) making a selection.

An example of how this process would work is contained in the following hypothetical example where a Marine Corps organization has decided to purchase some quantity of workstations. The organization has the option to select workstations that have 166MHz processors with 256KB cache

and 32MB RAM (Option 1)or workstations that have 200MHz processors with 512KB cache and 64MB RAM (Option 2).

The first step in the process would be to generate potential scenarios. Two scenarios might be:

- The workstations will be compatible with Marine Corps' software standards for more than five years.
- The workstation will not be compatible with Marine Corps' software standards for more than five years.

The next step would be to identify costs and benefits of each scenario. Table 6-1 gives simple hypothetical costs and benefits of each scenario.

Costs and Benefits of Each Scenario

Options	Purchase Cost $	Productivity Benefits $	Replacement Cost $	Total Cost/Benefit $
Option 1				
No Replacement	(300K)	500K		200K
Replacement	(300K)	500K	(500K)	(300K)
Option 2				
No Replacement	(400K)	550K		150K
Replacement	(400K)	550K	(500K)	(350K)

Table 6-1 (Researcher, 1997)

It is at this point, or concurrent to the process, that the CCR Program Office would survey key IT procurement personnel to come up with an estimation of the categorical classification of the items comprising the systems of Options 1 and 2. Other alternatives might be to cull this information from existing databases (previous Wenger

surveys) or combine the results of all items to derive a system classification.

For this particular case, the researcher would be particularly interested in how the characteristic "change" (C1) affected the classification of the items. Referring to Chapter V, Tables 5-1 through 5-4 show that, as a group, processors have higher placement with respect to change(C1) than all other computer items. In Tables 5-1 through 5-3 each processor displayed the highest "change" ranking in each survey (4.80, 4.08, 4.22). Furthermore, no other item in Tables 5-1 through 5-4 displayed rankings this high. Additionally, Table 5-11 shows that this characteristic significantly contributes to the high-end categorical placement of processors because all processors fall into the first group. Finally, as exhibited by Table 5-9, processors generally have higher (categorically more complex) cumulative averages than nearly all other items. If one assumes that evolving software will continue to require greater processor speed and greater levels of cache, and that the Marine Corps will continue to upgrade or replace its software capability in concert with industry, then decisionmakers should be concerned with the capability of the processors in their systems. Based on historical information (how often the Marine Corps makes significant

software changes) decisionmakers could then assign probabilities to the given scenarios.

At first glance, the above discussion seems obvious. What if, however, advances in processor technology slowed or stumbled? It is entirely possible that other items in a system would become comparatively more categorically complex. Decisionmakers might then base their decisions and assumptions on different factors. Repetitive (maybe biannual) Wenger Model surveys could highlight trends in critical COTS IT items. This would give procurement officials "advance warning" of changes in the industry. It could prevent personnel from being influenced by entrenched preconceived notions.

Returning to the example, CCR Program Office personnel and the user could use the information obtained from the Wenger Model to assist them in the fourth step of the process: to assign probabilities to given scenarios. For example, if the categorical placement of processors was relatively high then one might assume that the technology will continue to change and that other processor technology (greater capability than that provided in the Options) would be available within the next five years. The question then becomes: If the Marine Corps upgrades its general use software, will the equipment contained in the Options still be compatible with the software? Personnel would estimate

the likelihood of this occurrence. For this example, the researcher assigned the following probabilities:

Option 1	(No replacement)..........	80%
	(Replacement).............	10%
Option 2	(No replacement)..........	95%
	(Replacement).............	5%

With the given cost-benefit estimations and the projected probabilities, the CCR Program Office and the user could then calculate cost-benefit streams. Simply, for both options, this is the sum of the products between P(no replacement)and cost-benefit(no replacement) plus P(replacement)and cost-benefit (replacement). With the given data, Option 1's cost-benefit stream is $100K and Option 2's is $160K. Clearly under this scenario, the greatest benefit would be to select Option 2 (workstations that have 200MHz processors with 512KB cache and 64MB RAM). If, however, decisionmakers felt that the probability of replacement were the same for both options (5%) then Option 1's cost-benefit stream would be $175K versus $160K for Option 2.

Admittedly, this is a simplistic case. It does not account for a decisionmaker's utility with respect to his or her aversion to risk. The researcher also recognizes that many other factors affect IT procurement decisions (budgets, mission, etc.). The point, however, is that the CCR Program Office personnel and users could use the Wenger Model to

gain greater understanding about particular items. This understanding could affect one's decision concerning which IT system to procure and ultimately have a positive impact on the quality of the IT investment.

C. EVALUATION FACTORS

The researcher believes that the COTR section of the CCR Program Office could benefit from using the Wenger Model in the area of evaluation factors. This is particularly true in the area of simplified acquisition. As discussed in Chapter III, the COTR section, in part, recommends MCHS equipment acquisition solutions for identified requirements by searching available Federal IT contract vehicles (Marine Corps, 1997, pp. 1-4). Unless the equipment is ruggedized, it is entirely commercial. Oftentimes, the total requirement is less than the Simplified Acquisition Threshold of $5 million for commercial items authorized by the Clinger-Cohen Act. Frequently, total requirement costs are less than $100,000. Unlike years past, these facts allow the CCR Program Office to use evaluation factors other than price when making an award. The ability to do this is critically important in an environment where there are numerous IT contract options available. It is equally important because the IT industry bundles their configurations, thereby creating an environment where the DoD might be compelled to accept the available products or

be prepared to pay a higher price for specifically tailored configurations. Smart IT investment decisions must consider factors other than price.

The Wenger Model could provide the CCR Program Office personnel with the ability to more precisely evaluate other factors. Referring to Chapter V, Table 5-11 showed that complexity(C2) had an important but diminishing impact on the categorical placement of an item as an item's categorical ranking decreased. With this knowledge, personnel could theoretically equate this to the performance of systems offered by various companies.

For example, Company A offers a wide variety of products that range across the categorical spectrum from simple to complex. Customers are generally happy with the performance of the systems and items where complexity(C2) is considered categorically simple to moderate. As the categorical ranking of complexity(C2)increases, however, customers become less and less satisfied with the product. Furthermore, customers become less and less satisfied with their relationship with company representatives as the categorical ranking of the product's complexity(C2) increases.

Company B also offers a wide variety of products that range across the categorical spectrum from simple to complex. Unlike Company A, customers are uniformly

satisfied with the product and the performance of the company as the equipment's complexity(C2) increases in categorical ranking. Company B's products, however, are always more expensive than Company A's.

CCR personnel could use the Wenger Model to make a "best value" choice between the two companies. They could establish a categorical value threshold for complexity(C2) where anything above a certain value would indicate that they should procure from Company B, despite the higher price, because the trade-off for better performance and service would be worth the extra cost.

D. WARRANTIES

An area the CCR Program Office considers as fundamental to the success of the MCHS concept is the ability of the user to purchase warranty upgrades. All MCHS bundled configurations come with the option to purchase two one year warranty extensions. This option is advertised in the CCR "Computer Buyer's Guide." Presumably there is merit in this concept. The researcher, however, disagrees with the manner in which it is advertised.

The researcher believes that users who have extra funds and limited knowledge about computer hardware and the commercial marketplace will be inclined to purchase a warranty whether it is needed or not. The Wenger Model can

be used to help determine the value of purchasing a warranty. For example, the CCR Program Office personnel could determine categorical placement of various items and systems, and then determine to what level warranties are used at various categorical rankings. It might turn out that as the categorical values of change(C1) and complexity(C2) increase, warranty usage also increases. At some categorical level the failure rate might be so low that the cost of purchasing additional warranty coverage might not justify its purchase. In this case, the user might consider alternative methods of seeking repair that would be more cost effective. In short, the Wenger Model could help CCR Program Office personnel make this determination. With this knowledge, they could advise the user about the positive and negative aspects of purchasing the warranty rather than advertising it with no explanation.

E. CONTINGENCIES

Despite the potential benefits of using the Wenger Model, the survey process demands time and energy from both the buying activity and survey participants. The researcher believes that, sometimes, neither buying activities nor survey participants will have enough of either to go through the process. This might be particularly true when the requirement is related to a contingency.

At this point, however, the researcher feels it would be justifiable to use a predictive tool to estimate an item's categorical ranking. Referring to Chapter V, Tables 5-13 and 5-14 showed that individual values associated with change(C1), complexity(C2), unit cost(C7) documentation (C8), and stability(C12) had strong linear relationships with an item's overall categorical value. These relationships could be used to predict an item's categorical value and thus, aid the decisionmaking process.

Suppose, for example, that a Marine Corps unit was unexpectedly ordered to support a humanitarian operation. The unit decided it needed to purchase ten laptop computers (portables) to support the mission and the Commander was concerned about spending too much money for too much capability. Meanwhile, the CCR Program Office did not have any Wenger Model generated data concerning laptops. To overcome this deficiency, the CCR Program Office personnel could telephonically survey a reasonable amount of people. The survey would be limited to one of the characteristic that displays a strong linear relationship. They then could quickly assimilate the data and generate a value for the characteristic which could then be used in its associated linear relationship. This relationship would yield a reasonable prediction of an item's categorical ranking. This ranking could then be sent to the Commander so that he

or she could make a more informed decision about what type of laptop would meet his or her requirement and from whom to purchase the laptops.

F. ORGANIZATIONAL IMPACT

Another area that the Wenger Model is of potential benefit concerns the impact that IT procurements can have on the daily activities that a unit performs. New IT can affect or change training, operational procedures, communication of information, and workflow (Sherman, 1997, p.1).

K.A. Beeson, in a recent Masters Thesis, concluded that complexity(C2) was an important characteristic to evaluate when considering commercial products. She also concluded that:

> The more complex an item becomes, the more likely it is to have a unique or specific application. As the uniqueness of a product or its end item application increases, it becomes more difficult to identify valid or suitable substitutes. (Beeson, 1993, p.47)

To extrapolate on this concept, the researcher believes that because items become more unique as complexity(C2) becomes categorically higher, then (as suggested by Sherman in The FA&SM Group's News) training, operational procedures, communication of information, and workflow will be increasingly affected. (Sherman, 1997, p.1). Commanders need to know this before making IT investments. The costs

associated with these changes might not be worth investing in the new IT.

The CCR Program Office personnel can use the Wenger Model to evaluate items with respect to their categorical complexity(C2) and then determine if items or systems that have higher complexity(C2) actually do increase or change training, operational procedures, communication of information, and workflow. If it is true, then the Commander needs to assess whether the organization has the capability and money to provide the training and change operational procedures. Furthermore, the Commander must assess whether the organization is prepared to adapt new methods of exchanging information and new workflow. If these questions cannot be answered affirmatively, then the Commander needs to question the wisdom of purchasing an item or system that is so complex.

G. SUMMARY

This chapter presented five areas that the researcher feels could improve the CCR Program Office's capability to assist with procurement and to procure COTS computer hardware equipment. These areas included improving cost-benefit analysis, judging evaluation factors, warranty purchases, contingency contracting, and overall organizational impact. Improvements in these areas can lead to smarter, efficient, and more effective IT procurements.

The next chapter presents the conclusions and recommendations resulting from this study.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

This chapter presents the conclusions and recommendations resulting from this research effort. It also addresses the primary and secondary research questions and discusses areas for future research.

B. CONCLUSIONS

The following conclusions have been drawn from the research conducted in this study:

- **Commercial-off-the-Shelf computer hardware equipment can be classified using a modified version of the Wenger Model.**

A principal goal of this research effort was to determine what the results would be of using the Wenger Model to classify COTS computer hardware equipment. Concurrent to this goal was to determine if the original Wenger Model characteristics constituted the best mix for this type of classification. The researcher found that the Wenger Model was useful for classifying COTS computer hardware equipment. It adequately enabled one to differentiate and distinguish between various types of COTS computer hardware equipment. Despite this, the researcher found that a slightly different mix of characteristics provided better results.

- **Modification of the Wenger Model to include the following seven characteristics should provide better results: change, complexity, customization, maintainability, homogeneity, consumption, and documentation.**

Wenger's Model, which was subsequently validated by Prendergast, showed that six characteristics (complexity, customization, maintainability, unit cost, documentation, item attention) were sufficient to classify goods into five distinct categories. The researcher found that when classifying COTS computer hardware equipment a different set of characteristics provided better results. Specifically, the new set replaced unit cost(C7) and item attention(C9) with change(C1), homogeneity(C5), and consumption(C6). This set of characteristics more closely replicated the categorical values obtained when using all twelve characteristics than did the Wenger Model results.

- **Commercial Off-the-Shelf computer hardware equipment displays more categorically tighter values than previously tested sets of disparate and homogenous goods.**

Previous research showed that classifications of goods would result in items being categorized across the entire categorical spectrum of the Wenger Model (simple to complex). COTS computer hardware equipment, however, tends to display a much tighter pattern (low basic to mid-moderate). This is principally due to the limited

contributions many characteristics make toward differentiating items. For example, consumption(C6) had the highest average categorical score but the lowest range of scores. Consequently, this characteristic tended to raise the overall categorical value of an item (high average value) but did little to differentiate the items (tight range). If one only considered consumption(C6) when evaluating categorical placement of items, one would find it difficult to differentiate them.

- **The version of the Wenger Model developed by the researcher would be of benefit to procurement professionals involved in the acquisition of Commercial Off-the-Shelf computer hardware equipment.**

The researcher believes that when one uses a slightly different mix of characteristics than that used by Wenger, one can sufficiently differentiate items so as to gain strategic buying insight into COTS computer hardware equipment. This insight can be used in a variety of ways to improve the ability of procurement professionals to determine requirements and improve buying practices.

C. RECOMMENDATIONS

- **The Common Computer Resources Program Office should attempt to incorporate some aspect of the Wenger Model to improve their ability to make and to help the user make efficient and effective IT investments.**

The version of the Wenger Model espoused by the researcher has shown the capability to classify COTS computer hardware equipment to a degree which allows one to differentiate distinct differences between items. If one can logically differentiate between items then the implications of this are significant enough to justify considering using the model as a tool to improving buying practices.

The ability to classify COTS computer hardware equipment based on the suggested characteristics could provide insight into relationships between items and their procurement that are not readily apparent. CCR Program Office personnel do not have to apply the entire model to items of interest but can choose to use change(C1) or complexity(C2) to predict the categorical placement of an item.

- **Additional research should be conducted to determine if there are other characteristics that more adequately describe COTS computer hardware equipment.**

Previous research did not concentrate on COTS items. The characteristics used in this study were generated and tested by researchers who did not consider COTS as a distinct and separate family of homogenous goods. The researcher, however, relied on these characteristics to conduct this study. Quite possibly, there are other

characteristics pertaining to COTS computer hardware equipment that would improve the ability of personnel to differentiate items and to gain greater strategic insight with respect to those items. Such characteristics could include speed, capacity, interoperability, and commonality.

- **Classifying Information Technology systems might be a better or alternate method of attempting classification.**

During the course of this study, the researcher encountered many instances where survey respondents had difficulty envisioning individual items. Instead, many respondents wanted to classify individual items into their respective systems. From the researcher's point of view, this was understandable. Requirements personnel, buyers, and users generate, buy, and use IT equipment as systems. Furthermore, these systems are not supported in the traditional sense. When an item fails, the entire system is replaced or it is repaired by an external commercial source. It might be that procurement personnel view many of the items contained in this study to be nothing more than piece parts. Given this, it might be worthwhile to consider classifying COTS commercial hardware equipment at the system level with the capability of the system being a potentially critical characteristic.

D. RESEARCH QUESTIONS

The answer to the primary research question proposed in Chapter I is presented below:

Primary Research Question:

> **What would be the results of using the Wenger Taxonomical Model for classifying goods procured by the Federal Government when it is used to classify computer hardware equipment procured by the Marine Corps' Common Computer Resources Program Office?**

The results of using the Wenger Model to classify computer hardware equipment procured by the CCR Program Office show that all equipment is classified on a categorical spectrum from Mid-simple(1.60) to Low-moderate(2.96). Despite having fifty-one surveyed items, there was little differentiation between the items as compared to previous research efforts. This suggests that personnel generally do not distinguish much difference between the items comprising the family of COTS computer hardware equipment when they considered the characteristics of the Wenger Model.

Subsidiary Research Questions:

> **What types of computer hardware equipment typically receive high-end categorical placement and what are the contributing characteristics?**

The types of computer hardware equipment that typically received high-end categorical complexity were processors, ultra-wide SCSI controllers, and hot swap ultra-wide SCSI

drives. The characteristics contributing to an item's high-end categorical placement were almost universally change (C1), complexity(C2), and consumption(C6).

What are the principal differences and similarities between computer hardware equipment and their importance to the procurement process?

With the exception of change(C1), complexity(C2), and unit cost(C7), nearly all items were viewed similarly. Change(C1), complexity(C2), and unit cost(C7) are the characteristics that best differentiate items. As an item descends in categorical complexity so do the values of these characteristics. Other characteristics remain relatively constant. Although unit cost(C7) was not included as a necessary characteristic for the purposes of classifying COTS computer hardware equipment, the behavior of all three of these characteristics are important. Items associated with high levels of change(C1) and complexity(C2) should be scrutinized more closely than other items because the impact of their procurement can have stronger positive or negative impacts in the areas of cost, training, and benefit to the user.

How do the behavior of characteristics affect the overall categorical placement of all computer hardware equipment?

If a characteristic's categorical value has a large range across a number of items then one can deduce that the

characteristic will have a changing impact on the categorical placement of all items. If a characteristic's categorical value has a small range across a number of items then one can deduce that the characteristic will have a relatively equal impact on the categorical place of all items.

How can the Common Computer Resources Program Office and other Information Technology procurement professionals benefit from using the results obtained from the Wenger Model?

The CCR Program Office and other IT procurement professionals can benefit from using the Wenger Model or a derivative of it in a variety of ways. They can use it to improve cost-benefit analysis, contingency contracting, interpretation of source selection evaluation factors, assessing the overall impact the acquisition of IT equipment will have on organizational operations, and the usefulness of purchasing warranties.

What improvements or enhancements can be made to the Wenger Model to improve its ability to classify computer hardware?

The researcher believes that the characteristics used in the Wenger Model are not the best mix to use when classifying COTS computer hardware equipment. The study showed that change(C1), complexity(C2), customization(C3), maintainability(C4), homogeneity(C5), consumption(C6), and

documentation(C8) are the best characteristics to use for this purpose.

The researcher also believes that if a predictive tool could be developed, such as was suggested in this study, then it would encourage procurement professionals to use the Wenger Model. A tool which relied on only one or two characteristics would make collection of data much easier and less time consuming.

E. RECOMMENDATIONS FOR FURTHER RESEARCH

Use the same classification approach but use different characteristics.

There are many ways to describe a good. If as suggested by this study only three of twelve characteristics truly differentiated the items, then one can accept that as status quo or search for other relevant characteristics. This might entail going through the same procedures originally used by Wenger to develop his set of characteristics.

Concentrate survey efforts on one group of personnel at a time.

This study solicited opinions from a wide variety of sources. Responses were received from requirements personnel, buyers, users, logistical personnel, and senior level managers. Although the researcher did not have enough responses from any group to draw definitive conclusions, it

appeared that there were significant differences in the responses. This wide range of opinion may have contributed to the unexpectedly tight categorical range of the items. Insight might be gained if one were to assess the responses of these groups of personnel. Significant differences might indicate that there are different levels of understanding and interpretation throughout the procurement community.

F. SUMMARY

This chapter outlined conclusions and recommendations derived from the research. It provided answers to the primary and subsidiary questions and concluded with recommendations for further research.

APPENDIX A

WENGER MODEL CHARACTERISTICS

1. **Change** describes the good's rate of technological transformation. With some goods, their rate of technological change is very low. Their design is fixed and rarely, if ever, changes. Contrast this with those goods that are affected by state-of-the art technology and are characterized by a high rate of technological obsolescence.

SCALE:

1 Very low rate of technological change
2 Low rate of technological change
3 Medium amount of technological change
4 High rate of technological change
5 Very high rate of technological change

2. **Complexity** describes the good's technical intricacies. The degree of a good's technical complexity may be thought of in terms of the skill and expertise needed to produce the good. Another way to determine complexity is whether the good is a system, sub-assembly, component, piece part, or raw material. For scoring purposes, 1 indicates little or no technological complexity with 5 being very high complexity.

SCALE:

1 Very low technical complexity
2 Low technical complexity
3 Medium technical complexity
4 High technical complexity
5 Very high technical complexity

3. **Customization** is the degree to which the good is manufactured to the buyer's specifications. Some goods have no amount of customization while others are produced exclusively for a buyer. Goods that are not customized should be scored 1 with those developed exclusively for the Government scored 5.

SCALE:

1 No amount of customization
2 Low degree of customization
3 Medium amount of customization
4 High amount of customization
5 Made exclusively for the Government

4. **Maintainability** refers to the amount of maintenance considerations associated with the good. In other words, how frequently, if at all, is maintenance required on the good. Some goods are virtually maintenance-

free while others require a great deal of maintenance throughout their lives.

SCALE:
1 No maintenance required
2 Low maintenance required
3 Medium maintenance required
4 High maintenance requirements
5 Very high maintenance requirements

5. **Homogeneity** represents the number of other goods that are similar and are ready substitutes for the good under consideration. Typically, the more common the use of the good, the greater the amount of homogeneity. Highly homogeneous goods should be scored 1 and those with little or none scored 5.

SCALE:
1 Very high homogeneity
2 High homogeneity
3 Medium homogeneity
4 Low homogeneity
5 No homogeneity

6. **Consumption** refers to how rapidly the good is used by the buyer. Some goods are consumed on a continuing basis and require constant replenishment. Other are of a more permanent nature resulting in much less frequent buying. Rapidly consumed goods should be scored 1 and 5 used for goods that are rarely consumed or replaced.

SCALE:
1 Very rapidly consumed good, constant replenishment
2 Rapidly consumed good, constant replenishment
3 Moderate consumption and replenishment
4 Low rate of consumption and replenishment
5 Very low rate of consumption and replenishment

7. **Unit cost** is the good's cost to the buyer. Generally speaking, as a good becomes more unique to the buyer's requirement, the unit value increases. To score, use 1 for low unit cost and 5 for very high.

SCALE:
1 Very low unit cost
2 Low unit cost
3 Medium unit cost
4 High unit cost
5 Very high unit cost

8. **Documentation** is another characteristic external to the good yet many times a necessary part of it. Frequently the is the Government requires Government's requirement for substantiating documentation in the form of drawings, technical manuals, and certifications for some

types of goods. while for others little at all is required. When scoring, a 1 would indicate a good purchased with no accompanying documentation while 5 is for goods accompanied by drawings, technical manuals, etc..

SCALE:

1 No associated documentation
2 Low amount of documentation
3 Medium amount of documentation
4 Great deal of documentation
5 Very high amount of documentation

9. **Item attention** given by the buyer refers to single-item versus volume or mass buying. When a buyer deals with small dollar-value items like common bolts and rivets, the focus is on a mass quantity of these types or goods, Contrast this with the acquisition of a F-14 aircraft major weapon system where the buyer's attention is focused on a single item.

SCALE:

1 Complete volume-type attention
2 Mostly volume-type attention
3 Good that could be either volume or single good
4 Good that is usually single-good attention
5 Good that is always single-good attention

10. **Sources of supply** refers to the number of available sources that provide the same basic type of good. Some types of goods have associated with them a great number of alternate sources while others of a more specialized nature are more restrictive.

SCALE:

1 Virtually unlimited number of suppliers
2 High number of suppliers
3 Adequate number of suppliers
4 One or two sources
5 No sources exist

11. **Criticality** refers to the buying urgency associated with the good or the necessity of having the good available for the buyer to purchase. This characteristic of a good can be quite dynamic, but some goods, by their nature, may rarely be characterized as critical to the buyer.

SCALE:

1 Never characterized as a critical item
2 Rarely a critical item
3 Sometimes approached as critical
4 Usually characterized as critical
5 Always purchased under critical situations

12. Stability refers to the nature of the requirement. With some goods their demand is constant and seldom varies. On the other hand, demand for certain types of goods is much more volatile and uncertain depending on the need for the good and perhaps the technology that is available.

SCALE:

1 Item that is extremely stable
2 High degree of stability
3 Moderate amount of stability
4 Low amount of stability
5 Highly unstable good

APPENDIX B

WENGER MODEL GOODS

1. General Office Microcomputers
2. Fork Lift Trucks
3. Guided Missiles
4. Electronic Countermeasure Equipment
5. Paper Towel Dispenser
6. Pneumatic Chisel
7. Floating Drydock
8. 16MM Film Projector
9. Cold Food Counter
10. Submarine Periscopes
11. Filing Cabinet
12. Sandpaper
13. Aircraft Fire-Control Embedded Computer
14. Bottled Salad Dressing
15. Nuclear Reactors
16. Semi-conductor Assembly
17. Shipboard Washing Machine
18. Fluorescent Light Tubes
19. Pneumatic Tire (Non-aircraft)
20. Micrometer (General Purpose)
21. Flat Washers

APPENDIX C

CLASSIFICATION SCHEME

After results of a survey have been received and averaged, Wenger proposed that the data could be inserted into a classification matrix such as that displayed in Figure C-1. This matrix would allow one to quickly observe an item's average categorical placement and the categorical placement of individual characteristics.

Wenger Classification Scheme

Good:						N =
			Categories			
	Average Value	Simple (1.00-1.80)	Basic (1.81-2.60)	Moderate (2.61-3.40)	Advanced (3.41-4.20)	Complex (4.21-5.00)
Complexity						
Customization						
Maintainability						
Unit Cost						
Documentation						
Item Attention						
Overall Score						
Key:						
+ : UPPER END OF THE CATEGORY						
0 : MIDDLE OF THE CATEGORY						
- : LOWER END OF THE CATEGORY						

Figure C-1 (Wenger, 1990, p. 124)

APPENDIX D

COMPUTER ARCHITECTURE COMPONENTS

IBM Compatible (CISC) High End Server

This category targets a system capable of supporting a very large community of users including applications such as: transaction processing for large enterprise databases such as inventory, payroll, etc. Serving a large PC LAN workgroup for Internet access, groupware, and decision support. At minimum it consists of:
-Two 200MHz processors with 512KB L2 cache per CPU
-256 MB EDO RAM with error checking and correction
-Two 2.1 GB hot swap ultra wide SCSI drives
-A 4/8 GB internal DAT drive
-Dual channel PCI, ultra wide SCSI controller
-CD-ROM, 3.5" floppy drive, and redundant power supply
-A 10/100BT PCI network interface controller
-SVGA controller with 1024 X 768 resolution with 16 colors and 1MB RAM
-A 15" monitor, keyboard and pointing device
Upgrade options include:
-512 MB EDO RAM with error checking and correction
-Two 4.0 GB hot swap ultra wide SCSI drives
-Two 9.0 GB hot swap ultra wide SCSI drives
-Dual channel PCI, ultra wide SCSI, disk array controller

Table D-1 (Cruz, 1997, pp. 5, 13)

IBM Compatible (CISC) Midrange Server

This category targets a system capable of supporting small, medium, and large workgroups for applications such as messaging, groupware, small databases, and internet and intranet solutions. At minimum it has:
-200MHz processor with 256KB L2 cache
-64 MB EDO RAM with error checking and correction
-Two 2.1 GB hot swap ultra wide SCSI drives
-A 4/8 GB internal DAT drive
-Dual channel PCI, ultra wide SCSI controller
-An 8X CD-ROM and 3.5" floppy drive
-A 10/100BT PCI network interface controller
-SVGA controller with 1024 X 768 resolution with 16 colors and 1MB RAM
-A 15" monitor, keyboard and pointing device
Upgrade options include:
-Two 200MHz processors with 512KB L2 cache per CPU
-256 or 128 MB EDO RAM with error checking and correction
-Two 9.0 or 4.0 GB hot swap ultra wide SCSI drives
-Dual channel PCI, ultra wide SCSI, disk array controller
-Redundant power supply

Table D-2 (Cruz, 1997, pp. 6, 13)

IBM Compatible (CISC) Low End Server

This category targets a system capable of supporting departmental server applications for file and print services. At minimum it has:
-200MHz processor with 256KB L2 cache
-64 MB EDO RAM with error checking and correction
-Two 2.1 GB hot swap ultra wide SCSI drives
-A 4/8 GB internal DAT drive
-Dual channel PCI, ultra wide SCSI controller
-CD-ROM and 3.5" floppy drive
-A 10/100BT PCI network interface controller
-SVGA contr. with 1024 X 768 resolution with 16 colors & 1MB RAM
-A 15" monitor, keyboard and pointing device
Upgrade options include:
-Two 200MHz processors with 512KB L2 cache per CPU
-128 MB EDO RAM with error checking and correction
-Two 4.0 GB hot swap ultra wide SCSI drives
-Dual channel PCI, ultra wide SCSI, disk array controller

Table D-3 (Cruz, 1997, pp. 6, 13)

IBM Compatible (CISC) High Perf. Workstation High End

This category details a special purpose computer which is designed to meet the needs required by all but very few Marine Corps unique environments. At minimum it has:
-200MHz processor and 64 MB EDO RAM
-A 2.0 GB hard drive
-Enhanced EIDE controller
-An 8X CD-ROM and 3.5" floppy drive
-A 10/100BT network interface controller
-A 5.25" front load PC reader
-64 bit PCI graphics accelerator with 2MB video memory and upgrade capability to 8 MB
-A 17" monitor, keyboard, mouse and Flash Bios
Upgrade options include:
-Larger hard drive and 128 MB RAM
-4 or 8MB video memory for graphics accelerator
-19 or 21" monitor
-Soundblaster compatible audio

Table D-4 (Cruz, 1997, pp. 7, 13)

IBM Compatible (CISC) High Perf. Workstation Low End

This category details a special purpose computer which is designed to meet the needs required by most Marine Corps unique environments. At minimum it has:
-200MHz processor and 32 MB EDO RAM
-A 2.0 GB hard drive
-Enhanced EIDE controller
-An 8X CD-ROM and 3.5" floppy drive
-A 10/100BT network interface controller
-A 5.25" front load PC reader
-64 bit PCI graphics accler. w/ 2MB vid. mem. & upgrade capab. to 8 MB
-A 17" monitor, keyboard, mouse and Flash Bios
Upgrade options include:
-Larger hard drive and 64 MB RAM
-4 or 8MB video memory for graphics accelerator
-19 or 21" monitor
-Soundblaster compatible audio

Table D-5 (Cruz, 1997, pp. 8, 13)

IBM Compatible (CISC) Std. Appl. Workstation High End

This category details a general purpose computer which is designed to meet minimum needs required by all but very few Marine Corps office environments. At minimum it has:
-32 MB EDO RAM and 1.6GB hard drive
-Enhanced EIDE controller
-An 8X CD-ROM and 3.5" floppy drive
-A 10/100BT network interface controller
-A 5.25" front load PC reader
-64 bit PCI graphics accelerator with 2MB video memory and upgrade capability to 8 MB
-A 17" monitor, keyboard, pointing device and Flash Bios
Upgrade options include:
-Larger hard drive and 64 MB RAM
-4 or 8MB video memory for graphics accelerator
-19 or 21" monitor
-Soundblaster compatible audio

Table D-6 (Cruz, 1997, pp. 9, 14)

IBM Compatible (CISC) Std. Appl. Workstation Low End

This category details a general purpose computer designed to meet the minimum needs required by most Marine Corps office environments. At minimum it has:
-32 MB EDO RAM and 1.6GB hard drive
-Enhanced EIDE controller
-An 8X CD-ROM and 3.5" floppy drive
-A 10/100BT network interface controller
-A 5.25" front load PC reader
-64 bit PCI graphics accelerator with 2MB video memory
-A 17" monitor, keyboard, pointing device and Flash Bios
Upgrade options include:
-Larger hard drive and 64 MB RAM
-4MB video memory for graphics accelerator
-19 or 21" monitor
-Soundblaster compatible audio

Table D-7 (Cruz, 1997, pp. 9, 14)

Portable High End

This category details a small, lightweight general purpose computer, which is designed to meet the needs required by all but very few Marine Corps portable environments. At minimum it has:
-16 MB EDO RAM and 1.6GB hard drive
-A CD-ROM and 1.44 floppy drives
-A 10BT network interface controller
-2 PCMCIA type II slots
-Graphics controller with 1MB video memory
-28.8 KBps data/FAX modem
Upgrade options include:
-32 MB RAM
-2MB video memory for graphics controller
-Port replicator and docking station

Table D-8 (Cruz, 1997, pp. 10, 14)

Portable Low End

This category details small, lightweight, general purpose computer, which is designed to meet the needs required by most Marine Corps portable environments. At minimum it has:
-16 MB EDO RAM and 1.6GB hard drive
-A CD-ROM and 1 44 floppy drives
-A 10BT network interface controller
-2 PCMCIA type II slots
-Graphics controller with 1MB video memory
-28.8 KBps data/FAX modem
Upgrade options include:
-32 MB RAM
-2MB video memory for graphics controller
-Port replicator and docking station

Table D-9 (Cruz, 1997, pp. 10, 14)

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